DISSERTATIONES
PEDAGOGICAE
SCIENTIARUM
UNIVERSITATIS
TARTUENSIS
10

DAVID CERULLI

Investigating the Teaching and Learning of Natural Hazard Disaster Reduction

TARTU ÜLIKOOL · UNIVERSITAS TARTUENSIS · 1632

DISSERTATIONES PEDAGOGICAE SCIENTIARUM UNIVERSITATIS TARTUENSIS

10

DISSERTATIONES PEDAGOGICAE SCIENTIARUM UNIVERSITATIS TARTUENSIS

10

DAVID CERULLI

Investigating the Teaching and Learning of Natural Hazard Disaster Reduction

UNIVERSITY OF TARTU Press

Science Education Centre, Institute of Ecology and Earth Sciences, Faculty of Science and Technology, University of Tartu, Estonia

Dissertation is accepted for the commencement of the Degree of Doctor of Philosophy in Education on December 27, 2021 by the joint Doctoral Committee of the Institute of Education and Institute of Ecology and Earth Sciences for awarding doctoral degrees in education, University of Tartu.

Supervisors: Visiting Professor Jack Barrie Holbrook, PhD
Institute of Ecology and Earth Sciences, University of Tartu, Estonia

Professor Ülo Mander, PhD
Institute of Ecology and Earth Sciences, University of Tartu, Estonia

Opponent: Dr. Kari Sormunen
School of Applied Educational Science and Teacher Education, University of Eastern Finland, Finland

Commencement: White Hall of the University of Tartu Museum, Lossi 25, Tartu, on March 11, 2022, at 14:00

This research was supported by Target projects IUT-16 and PRG352 of the Ministry of Education and Science of Estonia and by the EU through the European Regional Development Fund (Centre of Excellence EcolChange) and by programme DoRa Plus and by Estonian Doctoral School of Educational Sciences (under University of Tartu ASTRA Project PER ASPERA), financed by the European Regional Development Fund.

European Union
European Regional
Development Fund

Investing
in your future

ISSN 1406-9709
ISBN 978-9949-03-817-6 (print)
ISBN 978-9949-03-818-3 (pdf)

University of Tartu Press
www.tyk.ee

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

API	Awareness and Preparedness Index
DRR	Disaster Risk Reduction
EF	Education Factor
LoA	Lack of Adaptive Capacities
LoC	Lack of Coping Capacities
NDR	Natural Disaster Reduction
NH	Natural Hazards
NHF	Natural Hazard Factor
NOS	Nature of Science
NOT	Nature of Technology
PISA	The Program for International Student Assessment
RBA	Responsible Behavioral Action
S	Susceptibility
V	Vulnerability
WRI	World Risk Index

LIST OF ORIGINAL PUBLICATIONS

The dissertation is based on the following original publications, which are referenced in the text as follows:

[P1] **Cerulli, D.**, Holbrook, J., & Mander, U. (2016). Devising an instrument for determining students' preparedness for an Education through Science learning approach within the topic of Natural Hazards. *Science Education International, 27*(1), 59–87.

[P2] **Cerulli, D.**, Scott, M. Aunap, R. Kull, A. Pärn, J. Holbrook, J. Mander, Ü. (2020). The Role of Education in Increasing Awareness and Reducing Impact of Natural Hazards. *Sustainability, 12*, 7623. https://doi.org/10.3390/su12187623

[P3] **Cerulli, D.**, & Holbrook, J. (2019). Exploring the Effect of NOS/NOT Learning and Dispositions on Undertaking Behavioural Actions in the Case of Natural Hazards. *Journal of Baltic Science Education*, *18*(4), 519–536. https://doi.org/10.33225/jbse/19.18.519

The author contributed to the publications as follows:

For Article I: Formulating research questions; creating and adapting the research model; writing the paper as the main author in collaboration with the co-authors; undertaking data collection for the pilot study.

For Article II: Planning and carrying out data collection and analysis for drafts 1 and 2; Writing the paper in collaboration with the co-authors.

For Article III: Devising the test based on the devised model and the outset map of an imaginary island; Planning data collection in public schools in three countries – Estonia, United States and Japan; Carrying out data collection, data analysis and writing the paper as the main Author in collaboration with the co-authors.

ACKNOWLEDGEMENTS

I am grateful to my supervisors Prof. Dr. Jack Holbrook and Prof. Dr. Ülo Mander, who introduced me to the world of science, and guided and supported me for years throughout my studies. I would also express my gratitude to all my co-authors Prof. Dr. Michael Scott, Dr. Raivo Aunap, Dr. Ain Kull and Dr. Jaan Pärn. A special thanks goes to Prof. Dr. Miia Rannikmäe, whose comprehensive help and consistency helped me throughout my studies and allowed me to finish my dissertation. Last but not least, I would like to thank my family for their patience, understanding and standing by me throughout the journey of doctoral studies.

1. INTRODUCTION

We live in a scientific and technological world, with major developments continually taking place in our lives. Despite this, science and technology, for the most part, are not able to predict natural hazards, for example, earthquakes. Nor has science and technology been able to play any meaningful role in eliminating natural hazards, both tectonic and meteorological. This is clearly a concern, especially as there is an increase in frequency and magnitude of meteorological natural hazards (Emrich & Cutter, 2011; Li et al., 2019), resulting from issues such as rising global average temperatures (Spencer, 2007; Dean, 2015) and a trend towards urbanization (Satterthwaite, McGranahan, & Tacoli, 2010). For instance, with the world's rising population, more people are being exposed to the impact of natural hazards than ever before in written history. This can be illustrated by citing the following examples of significant tectonic, natural disasters: the 2004 Indian Ocean earthquake and tsunami (Lay et al., 2005; Stone, 2005; Jankaew et al., 2008), where approximately 230,000 persons perished during the event, of which 60,000 persons were from at least 60 nations (Rabinovich, Geist, Fritz and Borrero, 2015) and the 2010 earthquake in Port au Prince, Haiti (Douilly et al., 2015), where at least 230,000 people died.

Apart from an awareness, in general, society seems poorly prepared to respond to tectonic and meteorological hazards in ways that save lives. This is compounded by the many different types of natural hazard situations and their lack of predictability. A current concern is enabling people to take meaningful evasive action, preferably voluntarily, based on responsible behavioral action, but otherwise by appreciating guidelines imposed from a level of authority. Furthermore, some nations are more vulnerable and susceptible to the negative consequences of natural hazards than others, especially countries with high population exposure to natural hazards, coupled with the greatest lack of adaptive and coping capacities. In some cases, steps have been heavily publicized so as to minimize loss of life, such as dealing with bush fires in areas like Australia and California (Stephens et al., 2009). However, being prepared to initiate steps in unexpected situations caused by natural hazards situations, where, for example, hikers on a Japanese mountain were forced to take evasive action from volcanic eruptions, or in New Zealand where tourists visited the crater of a volcano which suddenly erupted, means developing ways to promote actions by individuals, based on their own abilities.

An important concern associated with the mitigation of loss of life from natural hazards is the need to raise awareness of natural hazard exposure (Lerner-Lam, 2007) and gaining an appreciation of its importance within the society (Sword-Daniels et al., 2018). In the past, little research regarding the awareness of natural hazards has been undertaken (Dunbar, 2007). As a possible way forward for increasing awareness associated with natural hazards by a country, an attempt has been made to gauge awareness of natural hazards. Nevertheless, this index (UNU, 2016) is more associated with risk assessment rather than the role education can play in mitigating against natural disasters. There is a potential need for an index more dependent on the role of education with respect to ways of handling problem situations and preparedness for making life saving decisions.

An important consideration in mitigating against loss of lives, during or after a natural disaster, is the potential key role of education. Education can enhance the promotion of competences (in terms of values, attitudes, skills and knowledge) potentially enabling people to be better aware and also better prepared. However, the following with respect to science education, have been put forward as concerns:

- teaching in school has been shown to give little attention to developing transference skills (NRC, 2012; Oyao et al., 2015) such as being able to transfer responsible behavioral actions between real life threatening situations (ibid) from one natural hazard to another;
- curricula, especially earth science/geography curricula, are limited in their coverage of natural hazards and promoting ways to mitigate against loss of life (Estonian Government, 2011; NGSS, 2013; Multihazard Mitigation Council, 2018).

Nevertheless, in this respect steps are being taken to develop meaningful standards (NGSS, 2013). Although these can be considered as not going far enough in recognizing the importance of learning associated with the increasing frequency and magnitude of natural hazards, the need to include the transference of learning to new situations is recognized as important for taking responsible actions in the event of a natural hazard. This suggests that providing students with meaningful experiences, either real or simulated, can be seen as important (Iovine et al. 2006). Previously, curricula e.g. such as within the USA, typically tended to explain the science behind different forms of natural hazards, but not delve into learning associated with the taking of responsible actions in the event of such natural hazards (NRC, 2012).

A further concern is that the teaching of science subjects has failed to meet goals related to scientific literacy in the eyes of students (Stuckey et al., 2013). And there is little evidence to date that relevance of the learning is seen as a major focus of curriculum (NGSS, 2013).

Within earth science/geography, gaining a science and technology background can raise awareness of natural hazards and take steps to promote preparedness to mitigate natural hazards by:

- raising the level of societal awareness of natural hazards, i.e. raising the proportion of individuals who have knowledge of the existence of natural hazards (AghaKouchak et al., 2018; Wang & Ye, 2019);
- promoting knowledge that transcends topics in science, for instance the transference of learning from one topic to another, i.e. 'core ideas' (Semilarski et al., 2021);

- pay greater attention to enhancing 21st century skills which transcend subjects/ topics in learning including decision making, problem solving, communication, collaboration and system thinking (Rotherham & Willingham, 2010; Pellegrino, 2012).

1.1 Research Problem

Science education as promoted in schools is expected to go beyond knowledge acquisition towards enhancing scientific literacy (Holbrook & Rannikmäe, 2007). In enhancing scientific literacy, science curricula strive to go beyond science knowledge and encompasses beliefs, values and attitudes (Blazar & Kraft, 2017; Sheldrake et al., 2017). As a result, dispositions related to values and attitudes are expected to impact on how students are influenced, for example, in responding to new situations (Oyao et al., 2015). For example, even when mandatory evacuations are announced in the United States, it has been found that some individuals chose to ignore the warnings and stay in their homes (Rosenkoetter et al., 2007). Thus, the importance of including aspects of social interactions and raising awareness through all forms of education are being enhanced as common components in many curricula (Brown et al., 2018; Bronfman et al., 2019). And certainly, awareness of the potential dangers from natural hazards (NH) and developing associated dispositions can be seen as a potential first step towards reducing risks related to natural disaster reduction (NDR). It is thus not surprising that raising awareness of natural hazards is clearly an important educational component (NGSS, 2013) and besides the development of attitudes a further approach in science education is paying more attention to developing the ability to appreciate and undertake the transference of educational skills to new situations as a component of school science standards (NRC, 2012). The inclusion of developing problem-solving skills and resolving socio-scientific issues in teaching (Sadler & Zeidler, 2005; Lindahl et al., 2019; Zeidler, Herman & Sadler, 2019) are seen as factors that positively impact on the handling of potential natural hazards and through self-actualization, put forward meaningful ways of undertaking responsible behavioral action.

Prior research has tended to show that teachers' understanding of natural hazards is limited and teachers pay little attention to teaching this (Birkmann et al., 2014). Some countries (for example, Japan, Philippines and Indonesia) have included responsible actions to take in the event of a natural hazard (MEXT, 2009) in the state science curriculum. This is because teachers are more likely to place an emphasis on NH and NDR if included in the curriculum. In this respect, self-actualization models have been put forward in the literature (e.g. Maslow, 1943) but although they focus on survival, they lack a clear focus on the need for putting forward responsible behavioral action seen as an essential component for natural hazards disaster reduction (NDR).

Potentially, an additional problem in the teaching of science is that students (McComas, 1998; Lederman, 2007; Fernandes et al., 2017) and even teachers (McComas, 1998; Govender & Zulu, 2017) do not possess an adequate understanding of what is science (i.e. the meaning or the nature of science, often referred to as NOS), nor even the nature of technology (NOT). This concern goes beyond earth science teaching and points to a need to consider the importance of NOS and NOT for increased science and technology conceptualizations and the role these can play, both in science teaching in general and in the teaching of natural hazards in particular, points especially to the following concerns:

- students lack the ability to use their science and technology learning in new or practical situations (NRC, 2012);
- while curricula may focus on raising awareness of natural hazards, they pay little attention to responsible behavioral action during a natural hazard event (NRC, 2012; NSTA, 2020), it seems curricula are poorly prepared for this.

A poor understanding of the relationship between science and technology and NDR is a concern in seeking to promote responsible behavioral actions in the case of natural hazards.

1.2 Aim of the Research

The aim of this research is to investigate the emphasis being paid to relating the teaching and learning associated with natural hazards and to promote the taking of responsible behavioral actions against the negative impacts of natural hazards. In so doing, this research sees the need to re-examine teaching/learning models suitable for science and natural hazard education, based on educational theories as well as exploring the potential creation of an awareness and preparedness index (API) against natural hazard situations. The research further seeks to determine student and teacher conceptualization in recognizing the role of NOS, NOT as well as beliefs, attitudes and values, to develop self-determination with respect to NDR in natural hazard occurrences.

The following research questions are put forward:

1. With what features and to what degree can a meaningful, country-related index be devised for identifying the role of education as per the devised model in the realization of natural hazard awareness and preparedness? [P1];
2. To what extent can a suitable theoretical model and teaching-learning model be devised associated with enhancing the teaching of science education in general and natural hazards in particular? [P2];

3. To what extent are students, in three specific countries, able to handle natural hazard situations noting the associated learning progression needs with respect to the devised model? [P3};
4. What perceptions and opinions exist among teachers with respect to their preparedness to apply the devised theoretical/teaching model related to the teaching of natural hazards?

2. LITERATURE REVIEW

The literature review encompasses Natural Hazards, the Goals of Education and Teaching Approaches in Science Education. The Natural Hazards literature review encompasses Natural Disaster Reduction (NDR) and Disaster Risk Reduction (DRR). The goals of an education literature review encompass NOS, NOT, Dispositions, Constructivism, Behavioral Action and learning progression. Teaching approaches in Science Education included Education through Science, the three Level Teaching Approach and Self-Actualization.

2.1 Natural Hazards

Natural hazards occur in many different forms, are unpredictable, yet are a part of life. A natural hazard is defined by the United Nations International Strategy for Disaster Reduction (2009) as:

> "a natural process, or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage" (pp. 20).

Natural hazards can be meaningfully classified into two main types: tectonic and meteorological (Bokwa, 2013).

Awareness is a "knowledge or perception of a situation or fact" (Mahamuni et al., 2015, pp. 873) or a "concern about and well-informed interest in a particular situation or development" (Tara et al., 2015, pp. 355). Whilst preparedness is "the state of being ready for something to happen, especially for war or a disaster" (Munene, 2019, pp. 20). In other words, awareness is perception and understanding while preparedness is building readiness before the fact.

While natural hazards have been occurring throughout the Earth's history, an awareness of natural hazards has been linked to a direct relationship with experience (Astill, 2018). For example, in Japan, the nation with the highest frequency of earthquakes, citizens are generally more aware of earthquakes, rather than any other type of natural hazard, due to experience (MOFA, 2020).

There has been a plethora of research regarding actions associated with post-natural hazard responses (Loucks, Stedinger & Stakhiv, 2006; Collins & An, 2010; Kim, Woosam & Aleshinloye, 2014; Santos, et al., 2014), as well as involving disaster clean-up and restoration efforts (Burby et al., 2000). However, there has been a lack of studies relating to hazard responses while they are actually occurring (Shi, 2019) increasing the difficulty in undertaking curriculum development to include responses to reduce natural hazards (Sims & Baumann, 1983; Oyao et al., 2015). Natural hazards carry inherent risks and levels of exposure to natural hazards vary across the Earth (Wisner et al., 2004).

Natural Hazard Reduction and Disaster Risk Reduction

Reducing the risk to such hazards is clearly of major importance (Wachinger et al., 2013). International efforts to support countries with regard to such risks have been of major support for many countries. Noting that disaster risk reduction has attracted international attention, the United Nations used the phrase 'NDR' when naming the 1990s as the International Decade for Natural Disaster Reduction (Pisano, 1998). The International Decade for NDR was intended to reduce, through concerted international action, especially in developing countries, loss of life, property damage and social and economic disruption caused by natural disasters. Based on the 'Tokyo Declaration' (United States Government, 1992), an action plan for the International Decade for NDR, proposed by a commission of highly recognized experts, was drafted in March 1991 by an International Scientific and Technical Committee. Based on this international draft program, a framework for national scientific programs was developed by National Committees (Pisano, 1998). These programs were intended to reduce, through concerted international action (especially in developing countries), loss of life, property damage and social and economic disruption caused by natural disasters.

The specific aim of NDR is to promote behavioral action in the event of a natural hazard that mitigates against loss of life (WTO, 1998). However, since the 1990's, the term NDR has been under-utilized and Disaster Risk Reduction (DRR) has tended to become the predominant research term. DRR has been conceptualized as:

> "the practice of reducing disaster risks through systemic efforts to analyze and reduce the causal factors of disasters, lessening the vulnerability of people and property, wise management of the land and the environment, and improved preparedness for adverse events" (WTO, 1998, pp. 10–11).

DRR is a systematic approach to identifying, assessing and reducing the risks of a disaster (Jones et al., 2010). It aims to reduce socio-economic vulnerabilities to disaster as well as dealing with the environmental and other hazards that trigger them. Disaster Risk Reduction (DRR) refers, more specifically, to risk reduction in relation to natural hazards. NDR encompasses the teaching and learning of the taking of behavioral action during, or after, the event of a natural disaster. As the number of disasters triggered by natural hazards increases, NDR (as does DRR) clearly is an increasing area of importance (Shaw, 2020).

Natural Hazards Risk Index

To measure the risks posed by natural hazards, indices are seen as important (Gaiha, 2007), as they enable easy comparisons to be made by Governments, the media and individuals with the knowledge necessary (for instance, natural hazard safety knowledge) to provide indicators of the need to take measures to reduce risks and save lives (Rattien, 1990). Some indices, put forward in the literature with respect to natural hazards, are as follows:

- An urban earthquake disaster risk index (EDRI), is put forward by Davidson and Shah (1997). As an index, allowing risks to cities to be compared directly, relative to one another. The aim of the EDRI is to aggregate earthquake awareness components and interpret their implications (Davidson & Shah, 1997). For this, the authors present a model of human losses from natural hazards on the global scale, for the period 1980–2000;
- A natural disaster risk index has been devised by Peduzzi et al. (2009) to assess vulnerability and global exposure towards natural hazards and disasters. The aim of this index is to monitor the evolution of risks from natural hazards and disasters. To compile the natural disaster risk/awareness index, the authors utilize geographic information systems with a population distribution map overlaid with a model of natural hazards from cyclones, droughts, earthquakes and floods to determine global exposure to natural hazards and determination of risk;
- The World Risk Report (UNU, 2016) encompasses a World Risk Index (WRI), allowing comparison of countries on a global scale (Birkmann et al., 2014). The aim of the WRI is to demonstrate that "not only the magnitude, or intensity of a natural event influences disaster risk" but that a multitude of different factors, such as the political and institutional structures, the state of infrastructure, the nutritional situation and the economic and environmental conditions of a country determine whether a natural hazard is likely to turn into a disaster (Birkmann, 2011; Birkmann et al., 2014; UNU, 2016). The WRI focuses on the interaction of physical hazards and the vulnerability of exposed elements and is based on the general notion that the intensity of an extreme natural event is not the only factor of relevance in assessing a disaster risk; a society's level of development is also important. Thus, where the level of economic development is low, a society is more vulnerable to natural events than if it is better prepared, with increased financial support (funding) with regard to aspects such as vulnerability, susceptibility, coping capacities, and adaptive capacities (UNU, 2016). Vulnerability consists of the following components: susceptibility, lack of coping capacities, and lack of adaptive capacities (UNU, 2016), and relates to social, physical, economic, and environmental factors which make people, or systems susceptible to the impacts of natural hazards, the adverse effects of climate change, or other transformation processes. Susceptibility (UNU, 2016) is understood as the likelihood of suffering from harm in a natural event. Susceptibility describes the structural characteristics and framework conditions of a society (UNU, 2016). Coping comprises various abilities of societies to be able to minimize negative impacts of natural hazards and climate change through direct action and the resources available (UNU, 2016). Coping capacities encompass measures and abilities that are immediately available to reduce harm and damages in the occurrence of an event (UNU, 2016). Adaptation, as a separate entity from coping capacity, is understood as a long-term process that also includes structural changes (Birkmann & von Teichman, 2010) as well as measures and strategies dealing

with, and attempting to address, the negative impacts of natural hazards and climate change in the future. As with coping capacities, the lack of adaptive capacities, resulting from the value, is included in the World Risk Index.

2.2 Goals of Education

Education is expected to foster the development of students' abilities with the goal to become independent thinkers with a view towards enabling them to function within everyday life, solve problems and make decisions (Kervinen et al., 2020). Goals are crucial to determine educational success at school as well as in areas of life beyond the classroom (Bentley, 2012). Furthermore, setting and tracking attainment of educational goals help to guide students to gain important life skills such as planning, organizing and time management, while also building such attributes as communication skills, self-awareness and even confidence (Gould & Carson, 2008). Educational goals typically put forward attainable short-term goals and enable the creation of a teaching plan to achieve those goals (Bereiter & Scardamalia, 1989). Characteristics of goals in the learning of science encompass:

(1) enabling students to give, utilize and interpret scientific explanations of the natural world;
(2) generate and evaluate scientific evidence and explanations;
(3) understand the nature and development of scientific knowledge (Loucks-Horsley et al., 2009).

An education curriculum is broadly defined as the totality of student experiences expected to occur in the educational process (Wiles, 2008). As such, the term curriculum often refers specifically to a planned sequence of instruction based on the stipulated goals for education, often indicating a sequence based on national expectations (NRC, 2012).

In the US, the education provision is determined by each state and hence there is no specified national curriculum. Although since 2013, the Next Generation Science Standards (NGSS), have been devised centrally under the National Research Council (NRC), with the expectation in mind that the goals, represented by standards, are accepted nationwide (NRC, 2012). As of February 2020, 20 US states, plus the District of Columbia (https://ngss.nsta.org/About.aspx), have moved towards adopting this as a national science curriculum. NGSS places an emphasis on cross cutting skills, skills that transcend topics in education. Behavioral action is included in the Japanese national curriculum (MEXT, 2009) but there is a lack of any mention with respect to NOS and NOT. In the Estonian National Curricula, there are some mentions of NH and NDR, however references to NH and RBA are not consistent throughout the curricula.

Nature of Science (NOS)

Nature of science (NOS) is seen as a critical component of scientific literacy that enhances students' understanding of science concepts and enables them to make informed decisions about scientifically-based personal and societal issues (NSTA, 2020). An appreciation of NOS can serve as a strong foundation for indicating meaningful actions to promote timely NDR actions, as well as being better able to put forward scientifically appropriate, innovative technological approaches as meaningful ways of reducing loss of life.

Lederman (2007) has identified consensus aspects of NOS that researchers generally agree upon, providing a useful framework for indicating a meaning of NOS within curricula. Both Lederman and McComas (1998) put forward key NOS components as:

(a) scientific knowledge is tentative yet durable;
(b) there is a distinction between scientific theories and laws;
(c) there are creative, inferential and imaginative elements involved in the scientific process which should be recognized;
(d) empirical observations are based on real world evidence;
(e) scientific knowledge is culturally embedded;
(f) science is theory laden;
(g) science cannot answer all questions.

Nature of Technology (NOT)

It seems there is no one definition for NOT that is mutually agreed upon by educators, researchers and philosophers (Liou, 2015). NOT encompasses aspects of creativity and innovation, improvement and usefulness.

The role of technology in our lives is clearly of great importance and, for example, aids in detecting and responding to natural hazards (Manfré et al., 2012; Holdeman, 2014). Thus, gaining an understanding of the 'nature of technology' serves as a foundation for learning in science and engineering. Developing an understanding of NOT lends itself well to attributes associated with creative, critical thinking and development skills (Kabilan, 2000; Birgili, 2015).

NOT is not commonly found in curricula throughout the world (MEXT, 2009; NGSS, 2013), nor is NOT mentioned frequently in research because of a lack of consensus view (Liou, 2015). Technology has a scientific conceptualization (Constantinou et. al., 2010), however, there is ample evidence to suggest that technological developments can and do occur without the need for an understanding of the science, or despite the limitations of science (Jin & Yang, 2013). In fact, much technology arises from creative thinking (Deren et al., 2017) and the ability to adapt to new situations (Collie & Martin, 2016).

Three potentially important NOT aspects that have been put forward in the literature and relate to NH teaching are seen as:

(a) technology is useful. It is thus appropriate to seek ways of applying technology (Raka & Astawa, 2014). For example, because technology can help to reduce risks in the built environment, it is useful to implement natural hazard warning systems, such as those related to hurricane and lightning occurrences (David & Rangaswamy, 2014);

(b) a useful technological process needs to be creative and innovative (AAAS, 1993). Existing technologies are replaced if they can be improved upon, while novel methods, which are developed through original thinking are both creative and innovative. For example, modern seismographs to detect earthquakes are innovative in that they make use of smart technologies to be more sensitive (Dunnahoe, 2016);

(c) technology improves (AAAS, 1993). This suggests that the more appropriate the technology, the better. An important consideration for technology, therefore, is that steps are always being taken to make improvements. For example, improvements in the speed and performance in computing power enable the development of more robust predictive models in natural hazard warning systems and the improvement of physical infrastructure resilience (Pampanin, 2015), reducing risks in the event of a natural hazard. Improvements in technology as it relates to natural hazards have been applied to tsunami warning systems, reducing risks (Bernard & Titov, 2015). For example, following the December 26th, 2004 tsunami in the Indian Ocean, tsunami early warning systems (Lovhølt et. al., 2014).

Dispositions

The OECD (2019) uses the term 'dispositions' to refer to values, attitudes and beliefs, including a sense of responsibility and interest. Research relates dispositions to taking responsibility (UNICEF, 2012), with adaptability and flexibility (P21, 2008; Anderman, Sinatra & Gray, 2012) and developing the capability to become self-directed learners with a view towards lifelong learning (P21, 2008; UNICEF, 2012). Dispositions play a valuable education role with respect to establishing responsibility and taking actions (Oyao et al., 2015). Thus for example, in wishing to minimize the risks of natural hazards, positive dispositions have been shown to have a direct relationship with meaningful behavioral action and associated risk reduction (Najafi et al., 2017; Brown et al., 2018).

As attitudes and values play a part in any socio-scientific decision-making process, alongside skills and knowledge, dispositions are viewed as a component, contributing to behavioral actions (Siribunnam et al., 2014; Oyao et al., 2015). Dispositions (attitudes, mindsets, and beliefs) are seen as key dimensions of effective learning (Guthrie et al., 2004; Popham, 2009) and serve as a precursor for undertaking responsible behavioral action (Oyao et al., 2015).

Behavioral Action

Behavioral action refers to an ability to respond to an event, in a manner that is potentially the safest (Sims & Baumann, 1983; Oyao et al., 2015). Responsible actions to take during the event of a natural hazard have been shown to reduce risks and thus saving lives (Oyao et al., 2015). Behavioral action often involves a combination of creative thinking (Gupta & Sharma, 2019) and acting responsibly (Sims & Baumann, 1983) and thus behavioral actions are especially important in dealing with natural hazards (Oyao et al., 2015). An ability to put forward and undertake behavioral action, for example, in the event of a natural hazard is put forward (Oyao et al., 2015) as enabling the promotion of NOS, NOT, dispositions and it is this thinking that can lead to increased NDR. Research has shown that developing responsible actions to take during the event of a natural hazard or disaster is seen as an apex goal of learning with respect to NH/NDR (NRC, 2012). However, there has been little research into education's role in the need to develop competence in undertaking behavioral action, especially with respect to natural hazards (Kropivnitskaya, 2016).

Constructivism

An important approach to learning is for students to be guided to develop meaning (Beaton, et al., 2010). Constructivism, as a theory, relates to how students construct knowledge (Alsharif, 2014; Bada & Olusegun, 2015), recognizes that a learner's understanding and knowledge is based on their own experiences (Vygotsky, 1978) which relates to constructivism where students construct their knowledge through experience. Constructivism typically develops thinking skills, communication and social skills, rote memory learning, alternative methods of assessment, helps students transfer skills to the real world and promotes intrinsic motivation to learn (Moore, 2005).

Social constructivism is a variety of cognitive constructivism that emphasizes the collaborative nature of learning. In science education, research has shown that through a social constructivist approach, students are guided to put forward ideas and discuss those ideas with other students such as undertaking behavioral action in the event of a natural hazard or disaster (Powell & Kalina, 2009; Mishra, 2014). Research has indicated that applying social constructivism to the development of teacher-learner materials suggests that in promoting a social constructivist approach, a teacher can:

(a) create real world environments that employ the context in which learning is relevant;
(b) focus on realistic approaches to solving real world problems;
(c) stress inter-relatedness, providing multiple representations or perspectives on context (Bhattacharjee, 2015).

The successful learner is therefore one who assimilates new experiences alongside old and for whom understanding encompasses the new experience. Social constructivism is a way of learning for the student and a way of teaching for the teacher (Knapp, 2019).

Research has suggested (Kubieck, 2005) developing and sustaining a culture of inquiry in the classroom where the strong interface between students' everyday knowledge and school knowledge take place, to make learning more meaningful for students. Mishra (2014) has recognized from the research outcomes undertaken on creativity, technology and education that knowledge should be viewed as a co-constructed, negotiated and situated entity. The knower should have agency and the voice in the process of knowing and the process of learning should be dialogic.

Learning Progression

A learning progression is a carefully sequenced set of building blocks for students to master, en route to mastering a more distant aim (Popham, 2007). Schneider & Plasman (2011) define learning progressions as the successively more sophisticated ways of thinking about an idea that follow one another over a broad span of time. Within education a learning progression is intended to guide students to master more basic, less cognitive and value-laden learning at lower levels, while at the same time, encouraging them to strive towards involvement in more demanding cognitive (Bloom, 1956), affective (Irvine, 2017) and psychomotor learning at higher levels (Njura et al., 2020).

A learning progression is important because it can scaffold learning (Shea & Duncan, 2013) to construct knowledge that would otherwise be un-constructible by students on their own (van Aalst, 2009). A learning sequence is also important because learning progression tests can show that students do have some precursor skills and may be making progress so teachers can see areas of understanding from which to build (Stephens et al., 2017). Learning progressions better enable teachers to think about learners first, then to focus on teaching and the essential role of reflection for teachers is to rearrange their ideas in ways that develop their pedagogical content knowledge (Schneider & Plasman, 2011).

2.3 Teaching Approaches in Science Education

Teaching approaches in science education are an important area of research in science education. This section is limited in its coverage and focuses on teaching approaches that relate closely with the models put forth in Figures 1 and 2.

Education through Science

A meaningful direction for science teaching has been shown to be the adopting of 'education through science' approach (Holbrook & Rannikmäe, 2010). Promoting education through science as opposed to science through education (Holbrook & Rannikmäe, 2007) has been approached by researchers via a three stage model (Sormunen et al., 2014), connecting competences (values, skills, attitudes and knowledge) with pre-existing experiences (Holbrook & Rannikmäe, 2014). The advantages of utilizing an 'education through science' approach are that research has shown that education through science increases the relevance and meaning of lessons (Albrecht & Karabenick, 2018) enabling students to anchor learning on familiar competences (values, attitudes, skills and knowledge) (Chaudhry et al., 2020). Such skills can transcend across all subjects and therefore are not specific to science.

The Three Stage Teaching Approach

The three-stage approach is seen as appropriate for connecting student learning to relevant topics in science (Valdmann et al., 2020). In this approach to teaching science subjects, the initial (stage 1), is based on anchoring students learning on everyday experiences (Ausubel, 1960). Research has shown that Stage 1 contextualizes learning, making it more relevant and meaningful for students (Kotkas, Holbrook & Rannikmäe, 2017). During the second stage, teaching/ learning is de-contextualized so that competencies relevant to responses to natural hazards, such as scientific problem solving, learning is promoted, then re-contextualized (third stage) with a view towards relating content to real life situations or experiences. As teaching and learning progresses from stage 2 to stage 3, learning connects learning to meaningful everyday experiences (specific to the three stage model) seeking to increase the effectiveness of learning with a context that is familiar for students (Sormunen et al., 2014). Gilbert (2006) showed that context can relate content to personal and everyday experiences of students to provide more relevance to lessons by anchoring learning (Ausubel, 1960).

Self-Actualization

Maslow saw that the apex of his hierarchy of needs as self-actualization (Maslow, 1943), seeing this as the realization, or fulfillment of one's talents and potentialities, especially considered as a drive, or need present in everyone. Maslow's hierarchy of needs, as a form of motivational theory, was represented by a five-tier model of human needs, often depicted as hierarchical levels within a pyramid (Lonn & Dantzler, 2017). Self-actualization was seen as important because it allowed identification of strengths, weaknesses, and areas where improvement might be needed (Maslow, 1943). Of importance in self-actualization, rather than to judge or criticize, was to be aware and able to notice. The idea was that self-actualization was based on a hierarchy and in this case, the hierarchy was based on human needs (Hale et al., 2019).

As the ultimate goal in science education, with respect to natural hazards, is responsible behavioral action, physiological needs (Maslow, 1943) needed to be met as an important precursor. Any action or thinking undertaken by an individual for themselves, or for others, which increased safety was seen as supporting natural hazard disaster reduction (NDR) (United Nations, 1989).

Safety was a major consideration with respect to achieving responsible behavioral action (Oyao et al., 2015) in so far as it was prior to achieving responsible behavioral action in the event of a natural hazard. Survival research based on the need for basic *survival* learning, indicated there was potential to reflect on the idea that the theory could be modified to meet the need through making decisions leading to the need to take behavioral action.

Self-actualization could be perceived as developing needs to put forward behavioral action in the case of a natural hazard. In this way, education could play a role in enabling students to prepare for operating at the highest level of psychological development. Maslow (1943) applied his taxonomy with respect to basic survival needs and put forward a relatively straightforward progression from basic survival needs to higher-level growth needs which many found to be relatable to life experiences (Entwistle et al., 2001). However, research has shown that the progression towards self-actualization could be applied to relate to needs associated with being able to undertake action in the case of a natural hazard that was not only responsible but self-initiated.

3. DEVELOPING AN INDEX AND MODEL

In this study an Awareness and Preparedness Index (API) and a model for teaching NDR were devised. The API was devised with a view towards enabling measurements of Awareness and Preparedness for entire countries. The model for teaching NDR was devised with a view towards teaching and learning NDR.

3.1 Developing an Awareness and Preparedness Index

A natural hazard indicator (EF/NHF) was developed [P2], covering 15 countries, representing countries exhibiting natural hazards across the full global range (frequency, magnitude and exposure to droughts, earthquakes, hurricanes, floods (unrelated to hurricanes), mass movements, volcanic eruptions, and tsunamis) (Sivakumar, 2005). As this thesis relates to comparing natural hazard data from three countries, one in the Americans (US), one in Europe (Estonia) and the other in Asia (Japan), the derivation of the index was limited to the involvement of the following selected countries from these three continents – Bangladesh, Chile, Costa Rica, Estonia, Haiti, Indonesia, Ireland, Italy, Japan, Mongolia, New Zealand, Papua New Guinea, Philippines, Uganda and the USA.

Subsequently, a separate analysis was undertaken towards deriving a modified index, the awareness and preparedness index. For this, 30 countries were selected from the three continents. These countries were:

(a) from the Americas – Brazil, Canada, Chile, Costa Rica, Mexico, Panama, Peru, United States;
(b) from Europe – Belgium, Cyprus, Czech Republic, Estonia, France, Finland, Georgia, Ireland, Lithuania, North Macedonia, Portugal, Romania, Serbia, Slovak Republic, Slovenia, Spain;
(c) from Asia – Brunei Darussalam, Indonesia, Japan, Kazakhstan, Philippines, Singapore.

Initially, based on data provided in the World Risk Report, (UNU, 2016), the indicator developed in [P2] related to the determination of appropriate elements of vulnerability, as well as corresponding education levels (OECD, 2019, PISA scores), with a view towards analyzing relationships between education and vulnerability subcomponents of the World Risk Index.

The steps involved in developing the [P2] indicator were:

(1) deriving a vulnerability measure from the relationship between the WRI and exposure to natural hazards of extreme events in the selected countries;

(2) determining a normalized value i.e. a Natural Hazard Factor (NHF) for the countries of interest;

(3) determining an appropriate education parameter, independent of WRI. For this,
    (a) an indicator for the level of education was taken from OECD 2019 science test outcomes, or, where such a value was not available, by deriving such a 'pseudo' value by a relative association with GDP values;
    (b) determining a normalized Education Factor (EF) for the countries of interest;

(4) determining a relationship between NHF and the EF.

As a further development, science education (PISA 2018 scores) and WRI sub-components of, Lack of Coping Capacities, Lack of Adaptive Capacities, were re-compared with data from a larger set of countries. This led to deriving an awareness and preparedness (API) index, no longer specifically associated with risk, being developed with a view towards more appropriately examining the relationship between levels of science education and WRI components over a wider range of countries.

The 'preparedness' component was derived from meaningful education data i.e. derived by utilizing PISA 2018 scores for science (OECD, 2019).

To derive the NH indicator, vulnerability data were extracted from the World Risk Report (UNU, 2016). An XY scatter plot was drawn with a view towards best illustrating the relationship between two variables, an awareness and preparedness variable illustrated by a line of regression indicating a measure of 'best' fit amongst two variables. The awareness and preparedness indices were calculated based on the line of regression and presented for the 30 selected countries.

In the revised index, data on awareness were taken directly from the WRI report. Preparedness data were derived from the OECD-PISA science test component for 2018 (OECD, 2019).

Data were analyzed both in [P2] and in the revised index by:

1. extracted vulnerability and education data were normalized using SPSS;
2. the relationship between these two factors were determined by means of graphs using Excel;
3. the suitability of the graphs was determined by calculating R-squared in Excel.

Both the PISA and the WRI were taken as valid and reliable sources. PISA and the WRI were considered valid due to their presence in 88 countries.

The WRI is associated with risk and is in and of itself, an index. As a simple index indicator, the WRI is considered to be of sufficient validity because of acceptability based on 28 metrics, and derived in greater than 181 countries (UNU, 2016). It is valid to use the WRI index despite there being a lack of measurement units because it is a comparative measure of relative rankings. To increase the reliability of EF and NHF data, R-squared was calculated. R-squared is a statistical measure that represents the proportion of the variance for a dependent variable that's explained by an independent variable or variables in a regression model. The reliability of the derived relative vulnerability (RV) component is indicated by the R-squared value in the initial plot of WRI against exposure.

The models put forth in Figure 1 and Figure 2 encompasses a four level learning progression whereby the first three levels are literature related (Holbrook & Rannikmäe, 2010) with an additional fourth level for responsible behavioral action, while NOS, NOT and dispositions are taught and learned implicitly.

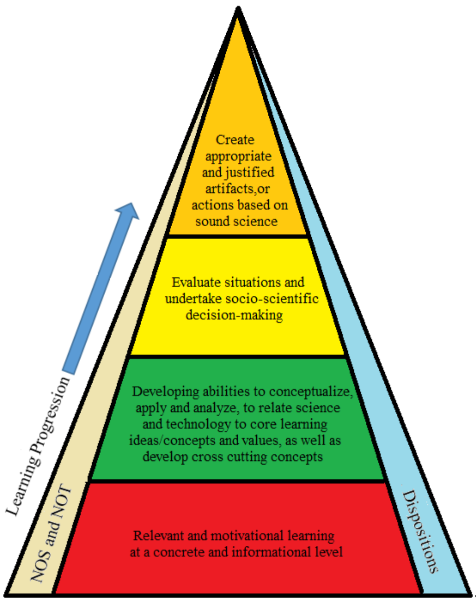


Figure 1. A hierarchical theoretical framework associated with an approach to science learning, with special reference to natural hazards.

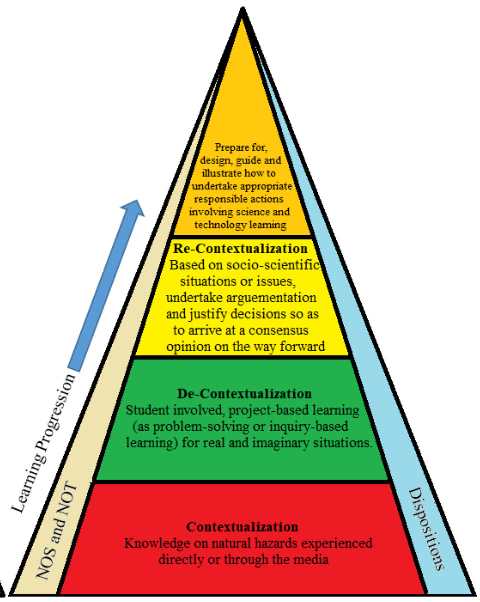


Figure 2. The hierarchical teaching Version of the model with respect to a teaching orientation in natural science, with special reference to natural hazards.

3.2 The Theoretical Model

The development of a model for promoting the teaching of natural hazards and promoting responsible behavioral action is detailed in [P1] and is based on the following aspects.

- The theoretical model focus, as put forward in Figure 1, encompasses a four level process, permitting learning from a lower anchor through to a meaningful, but increasingly educationally demanding, more sophisticated learning, at a higher anchor in line with that put forward in the literature (Oyao et al., 2015). Figure 1 is seen as relating to student cognitive development in the field of science education, as well as encompassing developments in attitudes and values, such as a willingness to appreciate the need to evacuate a building in the event of a natural hazard. In addition, the figure places value on the need to decide how gaining an understanding of the limits of science and technology can assist vulnerable populations during a natural hazard event.
- With students in lower grades, the contextual learning can be expected to initially focus at an informational level, while recognizing the importance of establishing comprehension as soon as practicable. From such a base, the educational progression can apply to real, or student relevant, situations, but theoretically, the cognitive learning is in line with following a cognitive hierarchy as put forward in Bloom's taxonomy (Bloom, 1956). At higher grades, the learning can be expected to put much more emphasis on learning associated with the analyzing and solving of problems (level 2), as well as gradually moving further towards evaluating situations and undertaking justified decision making (level 3), based on an expected, growing background associated with the nature of science (NOS) and the nature of technology (NOT) or engineering. Nevertheless, the ultimate target for the learning focuses on going beyond the making of meaningfully, justified decisions, involving social as well as scientific considerations, and to consider putting forward the need for responsible behavioral action, based on sound scientific and technological conceptualizations and positive dispositions (as amplified in chapter 2). For example, the target learning includes, from an earth science perspective, being able to put forward creative and scientifically meaningful actions either during, or after, natural hazard situations.
- Unfortunately, the literature suggests that little attention has been paid to the need for such actions and furthermore, for these actions to be considered in a responsible manner (Sims & Baumann, 1983; Oyao et al., 2015). Hence, the model recognizes the need to both promote greater attention to dispositions, such as establishing values, developing sound beliefs and also the development of intrinsically motivated and responsible approaches in education, and science education in particular, when dealing, for example, with natural hazard and risk reduction situations.

The second level in Figure 1 encompasses higher levels in Bloom's cognitive taxonomy, these being seen as encompassing comprehension, conceptualization and the application of the learning to real and new situations. Supporting this is promoting student self-development in putting forward problem solving ideas (Surya & Putri, 2017), promoting inquiry-based science learning (Dobber et al., 2017; Brown, 2017; Prayogi & Yuanita, 2018), and enabling such learning to be challenging and perhaps meaningfully described as project-based.

The third level in Figure 1 highlights the development of students' ability to learn beyond scientific cognitive problem solving and seeks to promote the ability to evaluate situations and make socio-scientific decisions (Zeidler et al., 2019; Johnson et al., 2020). This learning builds on problem solving competences, based on scientific conceptual ideas and requires the development of independent thinking from a social perspective (Gilbert et al., 2013) plus argumentation skills that involve interdisciplinary or social, sustainable and ethical considerations, as well as the ability to apply such competence learning to new situations. It places a strong emphasis on student's self-development (Ryan & Deci, 2002; Hui & Tsang, 2012) and self–efficacy (Bandura, 1971).

The ultimate target is student self-actualization (as described in chapter 2) in solving problems and making decisions in a responsible scientific manner. The fourth level in Figure 1 thus goes beyond decision making to enable the ability to plan for, devise and undertake, creative actions, which take note, for example in a natural hazard situation, of the need for responsible behavior. This can perhaps be best summarized as self-actualization (Maslow, 1943), although the need here is for students to be able to and have the confidence in undertaking meaningful actions, based on their decision making. And this being put forward while recognizing the need to behave in a responsible manner from a science, technology and human behavior point of view. In extending the learning beyond decision making, this represents the highest level of learning associated with taking responsible behavioral action associated with the upper learning anchor as proposed by Oyao et al. (2015). It envisages the action as not only being based on science, applicable to a given situation, but the action is seen as feasible i.e. doable in the perceived situation from a scientific and technological point of view. This also takes into consideration that decisions made are seen as responsible from a humanistic point of view (Bachmann, 2018) not only for those involved, but also for potential victims and those playing any form of supportive role.

Within the model, each level includes considerations of a progression in the affective domain, building from a 'willingness to learn' base (Morshead, 1965; Allen & Friedman, 2010). In addition, it builds progression in terms of how the psychomotor domain relates to the practical and proficiency considerations at a scientific and technological level. Thus, the proposed progression goes beyond a recognition of the need to promote cognitive and affective developments, but also involves actions related to psychomotor levels (Simpson, 1972) in line with Bloom's sensory taxonomy (Blackwelder, 1964). Aligned with the Bloom's affective taxonomy, the 2nd and 3rd levels in Figure 1 relate, from a theoretical perspective, with the development of students' active participation, collaboratively working with others, assessing, valuing and even enjoying the learning. The ultimate belief is the willingness to share values and ideas and guide the meaningful learning behavior of others.

Figure 1 indicates that NOS and NOT ideas are also developed throughout a learning progression so that consensus aspects of NOS and NOT, such as those agreed upon by researchers (McComas, 1998; Lederman, 2007; Hodson & Wong, 2017) are explicitly included throughout the learning progression towards the content and context of the teaching/learning (Fensham, 2009).

The model put forward in Figure 1 reflects on educational theoretical considerations but also on the manner and area of emphasis by which NH and NDR are taught and learned. This problem-solving learning forms a meaningful base for socially related (i.e. NH situations) decision making learning processes, where learning forms a base and leads to decision making by way of a progression and ultimately ascending to a higher level in the progression. Problem solving and decision making are key bases for the making of decisions and the taking of actions associated with responsible behavioral action in the face of natural hazards. Problem solving and decision making are seen as essential for undertaking RBA.

More specifically, the following elucidates the four theoretical levels:

Level 1 Level 1 is developed with a view towards being explicit by specifying natural hazards experienced directly, or through the media, in the teaching. It draws upon existing experiences and knowledge i.e. it involves factual information and the sharing of experiences. Level 1 encompasses student involvement so as to (a) motivate and (b) determine prior learning, relating to level 1 of the 3-level model. Level 1 is fundamental and hence the simplest and therefore tending to be the least tested of the four levels;

Level 2 At level 2, the model in Figure 1 focuses on conceptualizations of how natural hazards occur and natural hazard safety considerations are formed as essential building blocks towards developing responsible behavioral action in the event of a natural hazard. While the lowest level primarily focuses on factual learning, this level builds on the factual recall and extends cognitive thinking to encompass conceptualization. With conceptualization, the students are guided to think how to apply the learning to specific and even to new situations.

As this level relates to understanding, this affects dispositions as attitude towards giving explanations, rather than answers to simple questions on facts depends on student attitude towards responding. Level 2 corresponds with Bloom’s cognitive levels/stages 2, 3, and 4 regarding comprehension, application and analysis with respect to problem solving situations using science. In level 2, learning is more conceptual and requires problem solving abilities as per the expected curriculum (where NGSS can serve as an indicator);

Level 3 Practical/experimental level regarding evaluations. The phrasing in level 3 includes "applying suitable considerations" is more explicit and specific in Figure 2 and thus clearer for teachers to follow. Applying suitable considerations is clearer than putting ideas into context because knowledge is being applied in order to build up to level 4. Level 3 relates to evaluation, i.e. decision making, which is socio-scientific and includes ethics, moral, environmental, social and economic impacts. Students develop NDR skills with respect to map interpretation, recognizing actions that can be taken during a natural hazard scenario as well as putting forward meaningful and responsible behavioral action with respect to natural hazards and disasters.

Level 4 At level 4, the teacher is expected to be in a position to make use of different scenarios utilizing scenarios such as that laid out in Appendix 3 through a process of building up towards responsible actions to take in the event of a natural hazard. Within level 4 the learning encompasses that developed at all other levels as well as encompassing aspects of creativity and hence the major focus is taking responsible behavioral actions in the event of a natural hazard or disaster. The progression in the learning (which is conceptualization, not factual) reaches the highest level (self-actualization) through making responsible decisions.

3.3 The Teaching Approach Model

In an effort to put forward a model that is more operational and hence, teacher friendly and better suited to guiding teachers an interrelated teaching model is put forward in Figure 2. The ultimate goal in both Figure 1 and Figure 2 is for students to be willing and able to put forward responsible behavioral action in the event of a natural hazard or disaster. However, as learning in context is seen as important for establishing student motivation, as well as determining the background, (prior learning), of the students (Holbrook & Rannikmäe, 2010; Gershman et al., 2010). Figure 2 focuses on the learning progression within the teaching frame, based on an approach seen as contextualization, de-contextualization in gaining the scientific oriented competences and then re-contextualization to ensure the development of cross cutting, or interdisciplinary competences, especially decision making (Holbrook & Rannikmäe, 2010; Holbrook & Rannikmäe, 2014). While this frame is expected to relate to the teaching of specific topics, the emphasis on the de-contextualized, scientific conceptualizations increases with the learning progression over time, as does the re-contextualization in placing more emphasis on the need to put forward and justify, responsible behavioral actions. The progression within the teaching/learning levels within Figure 2 are elaborated below:

Level 1 – Contextualization – The learning is heavily based on contexts, especially those familiar to students (Holbrook & Rannikmäe, 2010). A major emphasis is to ensure the learning is motivational for students and also for the teacher to gain an indication of the students' prior learning, both in terms of the subject matter and also the level of thinking (Holbrook & Rannikmäe, 2010). A suitable context is intended which is seen as connecting with the prior experiences of students, either from real life, or from exposure via the media. An important consideration is to ensure the learning is both relevant and meaningful for students (Stuckey et al., 2013).

Level 2 – De-contextualization – In promoting a progression in the conceptual science learning, emphasis shifts from the contextual setting to the gaining of science competences through undertaking scientific operational gaining processes, such as those involved in problem solving within a scientific frame. In undertaking problem solving, the goal is not only to strive towards a determination of the scientific solution, but in gaining abilities to recognize how a problem can be tackled from a practical perspective though an inquiry-based approach, involving aspects such as:

- recognizing the problem;
- putting forward a realistic plan to solve the problem;
- undertaking experimentation based on selecting and utilizing apparatus in a scientific manner (for example controlling variables where this is applicable);
- determining data to be collected and suitably recorded;
- interpretation leading to a justifiable conclusion being put forward (Holbrook & Rannikmäe, 2014).

During such de-contextualization from the familiar or real-life context, the learning relates to the development of conceptual science learning, while also paying attention to safety attributes, for example, in mitigation against natural hazards. Such learning extends far beyond factual learning and promotes procedural knowledge, as well as meta-cognition and prioritizes the role of science in the development and operationalization of technological advances. Thus, the learning is in a science context e.g. in many cases a laboratory, utilizing science modules (Bolte et al., 2012), or other sources such as the textbook, so as to focus on the acquisition of the science ideas, science thinking, science procedures, experimentation methodologies, scientific interpretations, etc.

In level 2, the teaching and learning, with respect to conceptualizations of NOS and NOT is through the recognition that key components of NOS and NOT relate to seeing science and technology as being both creative and imaginative. NOS and NOT are integrated into science teaching through approaches in line with: "One fundamental goal for K-12 science education is a scientifically literate person who can understand the nature of scientific knowledge" (NGSS, 2013). Furthermore, establishing values, relating to an appreciation of scientific endeavors or the risks posed by natural hazards, form a further key area of development in level 2. Such student dispositions (both values and attitudes) are developed throughout the learning progression.

Level 3 – Re-Contextualization – The emphasis at level 3 is extending the learning to encompass socio-scientific decision making, which involves both the gaining of argumentation skills and relating to context beyond scientific considerations so as to relate the science to life or the society. The re-contextualization emphasis thus reconnects with the earlier contextual concern to enable the application of sound science competences for NDR, alongside other cross cutting aspects seen to be of importance associated with real life, e.g. considerations related to, for example, one or more of the following – economics, the environmental situation, political considerations, social awareness, ethical decisions, moral concerns (Chowdhury et al., 2020).

At this level, the nature of both science and technology is to facilitate the decision-making process at an individual, group, or class consensus level. The transition from an emphasis on conceptualization at the lower level to a de-contextualized platform, and then to an emphasis on the re-contextualization situation, is seen as extending student competences in a meaningful setting, enabling them to respond to social situations and events, such as a natural hazard, in a responsible and meaningful manner. This involves students eventually being able, at the appropriate grade level, to bring together their learning to enable scientific problem solving, socio-scientific decision making, and the development of communication, collaboration and systems thinking skills in an interdisciplinary manner.

At the level of level 3, it is expected students are guided to conceptualize that scientific knowledge is tentative yet durable, whilst technology is not only 'man-made', but is about improving on the prior, technological situation. With respect to the further development of dispositions at level 3, positive attitudes and values are expected to develop, not only related to the self, but are also seen of major importance with respect to the establishment of positive attitudes and values in others. For example, in a willingness to be involved in developing evacuation plans and planning for natural hazard risk reduction during science learning.

Level 4 – Responsible Behavioral Action – This level is thus seen as going beyond the justified and perhaps consensus decision making level and seen as the putting forward of meaningful actions, based on the decision made. This is of particular importance in dealing with natural hazard situations.

In putting forward a meaningful action, a strong emphasis is expected towards students being creative as well as utilizing conceptually appropriate science. This involves ensuring the learning associated with any action is put forward and explained in a responsible manner, taking note of the situational dangers, or concerns and also recognizing that the behavioral action is seen as suitable, meaningful and applicable in the given situation. This involves reflecting on NOS and NOT realities, as well as taking into account disposition (values and attitudes) factors. It emphasizes that the undertaking of responsible behavioral action can lead to reduced risks with respect to natural hazards (and in mitigating against loss of life during NH situations).

Level 4 is thus intended to promote student self-actualization through deriving responsible behavioral actions in simulated cases that build on contextualization appreciation, the gained scientific literacy capacities and the ability to be able to apply these to a new, or unknown, contextualized setting. Furthermore, level 4 draws on psychomotor skills necessary in order to physically or technologically respond to unknown situations, for example, a natural hazard, or disaster. This level is seen as largely absent from many curricula expectations, NGSS for instance, yet is seen as crucial in future learning especially in meaningful Natural Disaster Reduction (NDR) teaching/learning.

In developing such a new model (Figure 1 and Figure 2), firmly based on a learning progression, the focus is seen as putting forward a combined model, including cognitive, affective and sensory attributes (tri-level hierarchical taxonomies), building on a 3 level teaching of science approach to reach a 4^{th} upper anchor level (Oyao et al., 2015) seen as responsible behavioral actions, corresponding to the development of self-actualization. Progression is established in both the gaining of disciplinary subject competences and the gaining of interdisciplinary cross cutting concepts through students; self-determination and the actualization of responsible behavior actions. How far students are able to reach level 4 and encompasses behavioral action, based on socio-scientific considerations, is a feature of this research whereby the ideas behind the model are tested with students and teachers.

4. METHODOLOGY

This research investigates the impact of science education related to a derived teaching/learning model (Figures 1 and 2), with particular attention to earth science teaching and learning. It focuses on mitigation against natural hazards based on steps undertaken to promote awareness and preparedness in coping with natural hazards. For this purpose, a student test has been devised, validated and subsequently utilized, to determine students' self-actualization associated with undertaking responsible behavioral actions in the occurrence of a natural hazard. In addition, a teacher questionnaire has been developed to solicit teacher views on the value of teaching responsible behavior actions for Natural Disaster Reduction, related to the model (Figure 1 and 2). The responses are validated through 'expert' teacher interviews.

4.1 Student Test

Pilot testing

Based on the developed teaching-learning model (Figure 2), a student test was developed and piloted. Two pilot studies were undertaken. The first in Estonia and the second in the USA.

Sample

For the two pilot studies, a convenience sample of students in grades 6–12 from the 2 countries: Estonia and the United States was taken, as illustrated in Table 1.

Table 1. Student Samples for the Pilot Studies

	Country	City or State	Sample Size (N)	Timeline	No. of Intact Classes
1st pilot	Estonia	Nationwide	135	Autumn 2015	8
2nd pilot	USA	East Coast (Maryland)	55	Spring 2016	5

Instrument

The initial pilot instrument consisted of 17 Items. The first Item related to the perceived risks of natural hazards, followed by 5 Items related to NOS, 4 Items related to NOT and 4 Items testing dispositions (attitudes and values) through a context of natural hazards and disasters. In addition, an Item relating to the inter-relationship between science and technology, plus two Items relating to responsible behavioral action.

The administered instrument related (to any one student) to one of four natural hazards (Hurricane, Lightning, Earthquakes or Tsunamis) and also included an outset map, printed in color and designed to 'set the scene'. The instrument was devised and piloted with students in two public schools in Tartu, Estonia (in Spring 2015) and two public schools in Maryland, United States (also in Spring 2015). As the test was divided into 4 versions, student test data was analyzed based on NOS learning etc. from different Items for different students. In some cases, students responded to only one Item on NOS, NOT or dispositions.

During piloting in the US, the instrument was modified slightly, whereby one Item was removed because it was considered unethical by a school board in the United States. This 2nd pilot study (in the USA) was administered thus allowing the determination of potential differences in student responses to the test (between the piloting and the main testing). This was viewed as important because it increased the validity of the research instrument in that responses showed contrast between nations.

Data Collection

Student responses were obtained in a written format and any data added to the maps were also collected. In trying out the instrument, each student received both a set of questions formatted in 5 categories and a copy of the outset map, in print. Written directions were provided as follows:

i. *To the students* – Newspapers report that natural hazards are becoming more frequent due to climate change and population increase. Respond to the following questions related to natural hazards. Please respond to all questions. (In Estonia, students were requested to respond to the survey in English, if possible);

ii. *To the teachers administering the test* – Read the directions aloud to students for all questions, 1–5. Remind students to draw their route on the outset map. Ask if there are any questions before students begin their responses. Provide further assistance to any student who is struggling with following the directions given on the test paper.

The final instrument in the four different versions was administered in school to allow for two tectonic and two meteorological natural hazards, identified as Hurricane (H), Lightning (L) Earthquake (E) and Tsunami (T).

Data analysis

The data was analyzed utilizing MS Excel software. Means were computed based on the total number of responses. Bar graphs were generated based on percentage responses.

Undertaking the Main Test

Outcomes from piloting [P2] suggested that the instrument and the 4 natural hazard scenarios were suitable for main testing. However, the final test instrument differed in that the instrument was compiled in 4 different ways (sets), with questions amended to fit where appropriate [P1; P3] and each set relating to a different natural hazard (either Hurricane, Lightning, Earthquakes, or Tsunamis). The scenarios were also adjusted, based on student responses and teacher feedback during the pilot testing. Adjustments were made to the Items in the student test as well as adjustments made in the map in Appendix 3.

For the main testing, the test was compiled as 5 separate categories.

Category 1 consisted of one question asking students to indicate whether they had experienced hurricanes, lightning. earthquakes or tsunamis.

In *category 2*, the student test items were constructed in two Versions: Version 2A (compiled as likert scale response – agree or disagree) and Version 2B (compiled in a multiple choice format with 2–4 options provided per Item). Explanations (Version 2B) were sought with a view towards complementing likert scale responses (Version 2A).

The Items for NOS, NOT and dispositions in category 2 were presented separately [P3], for each of the 5 versions, and this is illustrated in Table 2, for each of the test Versions (Hurricane, Lightning, Earthquake and Tsunami). This unique combination of test Items resulted from a limit in access to participants.

Table 2. Distribution of Items (1–13) involving either Version 2A or 2A, indicated by hazard type

Category 2 Items	**Test numbers of Items in Hurricane Version**	**Test numbers of Items in Lightning Version**	**Test numbers of Items in Earthquake Version**	**Test numbers of Items in Tsunami Version**	**Test numbers of Items a General Version**
Version 2A – response only required					
Items related to NOS	3	1, 4, 5	1, 2	2, 3, 4, 5	1, 2, 5
Items related to NOT	6, 7	8	9	9	8, 10
Items related to dispositions	10, 12, 13	11	11	–	14

Category 2 Items	Test numbers of Items in Hurricane Version	Test numbers of Items in Lightning Version	Test numbers of Items in Earthquake Version	Test numbers of Items in Tsunami Version	Test numbers of Items a General Version
Version 2B – explanation choice required in addition to multiple choice question response					
Items related to NOS	1, 2, 4	3	5	–	–
Items related to NOT	8	6, 7	6, 8	–	–
Items related to dispositions	–	12, 13	10	10, 11, 12	–

In *category 3*, students were asked to describe the inter-relationship between Nature of Science and Nature of Technology. This was the same question in all 5 test versions.

Category 4 involved students in indicating a relative perception of risk for Hurricanes, Lightning, Earthquake, and Tsunami.

For *category* 5, students received either a Hurricane, Lightning, Earthquake or Tsunami natural hazard scenario and were asked to respond to the questions asked using the outset map as shown in Appendix 3.

Data Collection

Color prints of an outset map were provided for each natural hazard scenario (except lightning – See Appendix 3). Each student responded to only one behavioral action scenario (either Hurricanes, Lightning, Earthquakes, or Tsunamis), although each class received a combination of either Hurricane and Lightning, or Tsunamis and Earthquake scenarios to allow for administrative simplicity.

Data Analysis

Data was analyzed from administering the student test in each country/region. Data analysis was undertaken utilizing frequency counts, factor analysis, and determination of correlation coefficients using MS Excel and SPSS.

Validity and Reliability

Construct and content validity were checked both by consulting expert opinion plus from piloting and analyzing the feedback and further elucidated.

To determine validity, opinions were solicited from:

- Two associate professors seen as experts in earth science education;
- Three science teachers in the USA, responding individually.

The reliability of the student instrument was established by determining whether the data collected could be trusted. For this, three different perspectives of trustworthiness were considered:

- There were a high proportion of similar responses per Item, indicating trustworthiness because it showed that teachers were by and large responding in similar ways; Correlation coefficients between like variables and a relatively high Cronbach's alpha (a measure of internal consistency) further suggested dependability;
- The research instrument was checked with respect to quality assurance by teacher piloting of the survey. Ambiguities were highlighted and subsequent adjustments were made accordingly. Based on feedback provided by professors, further adjustments were made to the instrument;
- Careful consideration was given to ethical concerns. After discussion with two associate professors in science education, no ethical concerns were deemed to be included.

With respect to the student instrument, Correlation Coefficients were deemed meaningful to indicate internal consistency of the instrument. This was particularly the case where similar data was asked e.g. between Items 2 through 5; 6 through 9 and Items 10 through 14. The student test was validated for construct validity using expert opinion and piloting feedback. Where Correlations were high, there was a greater internal consistency for the instrument.

The instrument was initially piloted in Estonia by a master's degree student in Estonia (N=110). The instrument was subsequently piloted with 135 students in Estonia and 55 students in the United States as illustrated in [P1]. For all testing in Estonia, the research instruments were translated from English to Estonian by a science education student. Subsequently, the Estonian language instrument was translated from Estonian back to English and compared with the original research instrument to ensure accuracy of meanings and appropriateness of word choice.

4.2 Teacher Questionnaire

Teacher views and comprehension were solicited to determine earth science teachers' competence towards teaching about natural hazards and to probe teacher views and comprehension on teaching the nature of science (NOT), nature of technology (NOT), dispositions and Natural Disaster Reduction (NDR) and on the learning models put forward in Figures 1 and 2.

Sample

The sample consisted of 30 science teachers from the United States.

Instrument

Two interrelated instruments were compiled, based on the devised student test instrument:

(a) a teacher questionnaire compiled to ascertain a teacher's competence with respect to teaching approaches enabling student learning related to Natural Disaster Reduction (NDR), NOS and NOT. The questionnaire especially relates to conceptualizations, attitudes and values held towards teaching NOS, NOT and Natural Disaster Reduction (NDR). Whereas student competencies are developed alongside NOS and NOT throughout a progression of learning (as put forward in Figures 1 and 2). The further up the learning progression (see Figures 1 and 2), the more complex the teaching/learning associated with NOS and NOT and dispositions are;

(b) a second instrument consisted of an interview pre-format, developed to guide teacher interviews. This was undertaken to establish more in-depth and clarifying insights on the responses provided by the teachers for the teacher questionnaire.

The questionnaire consists of Items divided into 4 sections to include Items on (1) teacher background data, (2) Natural Disaster Reduction (NDR), (3) NOS and NOT and (4) responsible behavioral action.

Section 1 sought teaching data through two Items. Item 1 was included to provide background information on subjects taught (teachers were guided not to complete this survey if they did not teach a subject through which students learn about natural hazards), Item 2 solicited grade level of students being taught.

Section 2 sought the teacher's understanding of (a) NOS and (b) NOT, seen as important components in the devised models. This was thus to gain insights into components of NOS and NOT as valued by teachers and how far these related to teacher perceptions of earth science teaching with respect to natural hazards. Furthermore, Section 2 sought to determine teachers' conceptions of any interrelationship between NOS and NOT.

Section 3 probed teacher perceptions of Natural Disaster Reduction (NDR) associated with natural hazards. Items 8–14 relate to NGSS, this being taken as a meaningful curriculum focus based on teacher's attitudes and importance related to their dispositions about NDR associated with natural hazards. This section also sought teacher familiarity with NGSS. Item 8 probed whether teachers were familiar with NGSS, while Items 9 and 10 put forward specific passages from NGSS which relate to NDR. Items 11–14 relate to teacher views towards teaching NGSS/NDR in the classroom.

Section 4 probed teacher perceptions of responsible behavioral action and NDR, based on a 4 level learning model which addressed the construction of knowledge, beginning with contextualizing learning and building towards developing responsible behavioral actions in the event of a natural hazard, while implicitly including teaching of NOS, NOT and dispositions towards Natural Disaster Reduction (NDR) (that are related at the various progression levels in the model put forward in Figure 1). Teacher perceptions of teaching responsible behavioral action in the event of a natural hazard were probed. Teacher attitudes were included because it is put forward here that attitudes have an impact on teaching/learning.

Data Collection

Data collection was undertaken utilizing a written survey in New York and Delaware.

Data Analysis

Frequency counts and factor analysis were undertaken using SPSS.

Validity-Reliability

To ensure the validity of the questionnaire, opinions were solicited from:

- two associate professors seen as experts in earth science education;
- three science teachers in the USA, each responding individually.

Minor modifications, especially in wording, were made based on opinions given. The reliability of the instrument was established by determining whether the data collected could be trusted. For this, two different perspectives of trustworthiness were considered:

1) Dependability – Correlation Coefficients were determined between overlapping data, or variables (e.g. between Items 3 and 4). Cronbach's alpha was taken as a measure of internal consistency and was determined as a further indicator of dependability. The feedback from the interviews was also used to check the dependability of the questionnaire data.
2) Quality Assurance – The research instrument was checked with respect to quality assurance. Ambiguities were highlighted and subsequent adjustments were made accordingly. Based on feedback provided by professors, further adjustments were made to the instrument to increase its construct validity.

4.3 Teacher Interviews

The interview was devised and undertaken with a view towards complementing data from the teacher questionnaire. In the questionnaire sent to teachers, explanations were few and far between. Therefore, it was considered necessary to complement the teacher questionnaire data with a follow up interview to a carefully selected group of six teachers to gain insights as to why teachers responded to the survey the way they did. As the survey administered to the 35 teachers was purposely kept simple, i.e. the Items were straightforward so as to encourage teacher responses, further clarification on the reasoning for the responses (especially where there was diversity) given by the teachers was seen as important. This was ascertained by holding individual interviews with a small group of experienced teachers who were recognized as having taught, or planning to teach, about natural hazards in public schools. Further, the teachers participating in the interviews were considered to be experts in the fields of both education and earth science.

Two separate samples were solicited from the US East Coast with a view towards soliciting teacher willingness and preparedness to teach NDR.

Sample

A sample consisting of six earth science teachers, teaching grades 6–12 in the US, were mostly recruited during a professional development meeting for science teachers in Manhattan. These teachers, who were interviewed by telephone, were interviewed (after analysis of the 35 teacher outcomes) specifically to reinforce, or clarify, data from the teacher questionnaire responses from the first sample.

Instrument

In line with the sections in the teacher questionnaire and, highlighting aspects where the teachers' responses in the questionnaire were ambiguous, four key questions were asked to teachers.

Table 3. Key Questions Asked in the Teacher Interviews

Section	Key question asked by teacher interview
1	What do you understand by NOS?
2	What do you understand by NOT?
3	What is your interpretation of the degree of coverage of Natural Disaster Reduction (NDR) in the teaching of natural hazard?
4	How suitable do you feel is the proposed Behavioral Action approach for teaching Natural Disaster Reduction (NDR)?

In each case, subsidiary questions were asked, based on the interviewee's response to the key Item. The subsidiary questions took into account the responses from the teachers who had previously answered the questionnaire. Items from the teacher interview were put forward in Table 4.

Table 4. Subsidiary Questions asked in the Teacher Interviews

Item	Subsidiary Questions
1.1	When teaching natural hazards, how important is it to teach the nature of science?
1.2	Do you agree NOS relates to capability to be creative and show imagination?
2.1	Do you agree that the nature of technology can be expressed meaningfully by recognizing the following three potentially important aspects (i.e. Technology is: useful; needs to be creative or innovative; is an improvement in a given situation)?
3.1	In your view, how does NGSS differ from earlier approaches to Earth Science teaching?
3.2	Do you feel the cross-cutting concepts in NGSS sufficiently relate to natural hazards (NH) and *Natural Disaster Reduction (NDR)*?
4.1	Do you feel NGSS devotes sufficient attention to the teaching related to NDR situations both meteorological and geological?
5.1	Do you feel it is reasonable to expect students to be able to put forward responsible behavioral actions in case of a natural disaster, even in an entirely new situation, unfamiliar to the students?
5.2	How appropriate do you feel the teaching approach advocated in Appendix 3?

Data Collection

Data collection was undertaken over a period of approximately two weeks.

Data Analysis

A consensus opinion from these six teachers was sought by analyzing the results from the interviewed sample. Data analysis was carried out using SPSS and MS Excel. Outcomes obtained from the questionnaire were triangulated against results from the teacher interviews and the relevant literature.

Validity-Reliability

The reliability of the instrument was established by determining whether the data collected could be trusted. For this, two different perspectives of trustworthiness were considered:

1) Dependability – Correlation Coefficients were determined between overlapping data, or variables (e.g. between Items 3 and 4). Cronbach's alpha was taken as a measure of internal consistency and was determined as a further indicator of dependability. The feedback from the interviews was also used to check the dependability of the questionnaire data.

2) Quality Assurance – The research instrument was checked with respect to quality assurance. Ambiguities were highlighted and subsequent adjustments were made accordingly. Based on feedback provided by professors, further adjustments were made to the instrument to increase its construct validity.

5. RESULTS AND INTERPRETATIONS

Research findings were put forward associated with three key research areas, based on a theoretical model for teaching and learning, initially derived in [P2]. The key areas, related to natural hazards and disaster awareness, were an 'awareness and preparedness' index for country natural hazard situations, a devised student test, with data collected from three sampled countries, and subsequently, a teacher questionnaire administered and supported by interviews, to seek teacher responses to the expected learning or teaching emphasized in the model.

5.1 Deriving a Natural Hazard Awareness and Preparedness (API) Index

In devising of the NH-E indicator in [P2], the WRI (UNU, 2016) saw 'vulnerability' (V) as an important risk factor, being derived as the combined sum of Susceptibility (S), Lack of Coping Capacities (LoC) and Lack of Adaptive Capacities (LoA), with little or no attention to the role of education. Since preparedness to deal with natural hazards is highly dependent on the level of education the Preparedness factor was considered as a synonym for Education factor. For the estimation of education level the OECD PISA 2018 Science test scores were utilized (OECD, 2019). The PISA test is independent of the WRI factors and therefore suitable to characterize the role of education in coping with natural hazards.

To determine awareness components for the awareness and preparedness index (API), as a meaningful adaptation of the NH-E, graphs were plotted of education values for a meaningfully selected number of countries (seen as directly impacting on the preparedness component), against the inverse of WRI vulnerability indicators (thus allowing a positive slope). For meaningful comparisons, PISA (education) values, forming the x-axis, were normalized by converting to a range between 0 and 1, the value of 1 representing the highest value, in each case, from the selection of countries taken.

Noting PISA 2018 data were only available for 74 countries, mainly from Europe (OECD, 2019), a sample of these countries and from the 171 countries providing WRI data (Birkmann et al., 2014) was utilized. Furthermore, recognizing that the focus of the research in this thesis was with respect to NH/NDR related to US, Estonia and Japan, a meaningful sample of 30 countries were selected by omitting African/Australasian countries and limiting the extent of the large number of European countries by removing a country where data overlapped, or were very similar.

A Re-Determination of Awareness Related to Natural Hazards

A graph (Figure 3) was plotted of education data derived from 2018 PISA science scores against an awareness indicator of how to cope in a NH situation, which was derived as an average measure the indicator of coping capacity (1/LoC) and the indicator of the adaptive capacity (1/LoA), both components taken from WRI data (Birkmann et al., 2014). Data on LoA and LoC were preferably utilized because unlike the vulnerability and susceptibility data, they were seen as sub-components that were influenced by human endeavors and hence associated with the raising of an awareness.

Vulnerability was associated with risk rather than recognizing the danger. Susceptibility was seen as circumstantial, and thus also not an aspect of awareness. However, the location was recognized as important and thus the level of coping (1/lack of coping) and the level of adapting capacities (1/adapting capacity) were taken as the major factors in identifying the level of awareness of natural hazard disasters.

To explore the relationship between a preparedness indicator i.e, education using normalized 2018 PISA science data) and awareness indicator given by the inverse of an average of LoA and LoC, an XY scatter plot was plotted for the selected 30 countries, with a line of regression, as illustrated in Figure 3.

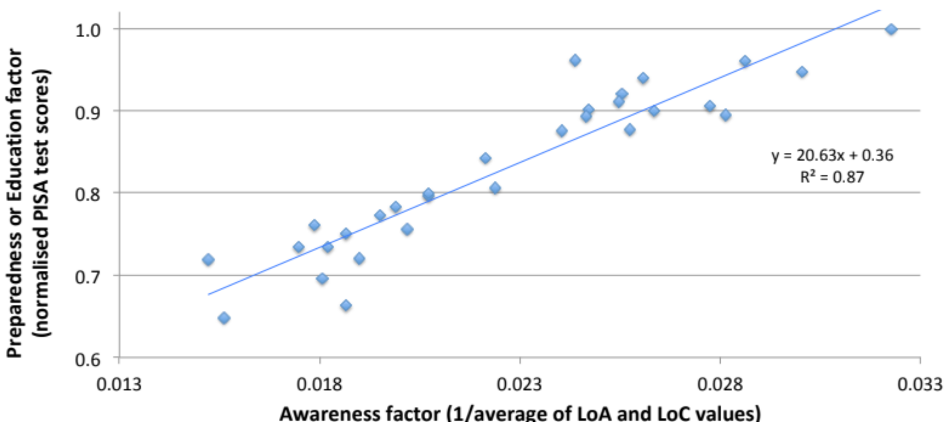


Figure 3. Relationship between the Awareness and Preparedness (Education) factors. Awareness = 1/((LoA+LoC)/2). World Risk Index (WRI) components LoA – Loss of Adaptive Capacities and LoC – Loss of Coping Capacities (Birkmann et al., 2014).

The regression line was determined to be: y = 20.63x + 0.36. The coefficient of deflection (range 0–1), gave an indication of goodness of fit, and was given by $R^2 = 0.87$. Noting the high R-squared value for the countries concerned, the awareness component in this thesis, was thus determined as the inverse of an average of the coping and adaptive capacity values.

Deriving an Awareness and Preparedness (API) Index for the 30 Countries

The awareness factor was calculated (for convenience by multiplying the preparedness and awareness factors by 100) to give the integrated awareness and preparedness index (API). The calculated API indices per country were sequenced from relatively high to low values. The derived awareness components, preparedness components and the calculated API values for the 30 countries were as given in Table 5.

The API data, given in Table 5, allowed for comparison across all 30 countries included in the sample. Based on this comparison, it was noted that Japan, Estonia, and the United States had relatively high API scores. This suggested that because of a relatively high level of education, the NH and NDR awareness were similarly positive. In general, countries within Europe illustrated a relatively high API, whilst countries in Asia exhibited a relatively low API with countries from the Americas either high or low. Students in Japan, a country with a relatively high API (268.8) was, in general, expected to reach the highest level for test data on responsible behavioral actions, as indicated in Figure 1 and Figure 2 (chapter 3). Thus, a high API was expected to correlate with a strong achievement of students in school. Students in school through earth science teaching were thus expected to aspire to appreciate RBA and show an understanding of the supportive learning components.

The API data, given in Table 5, allowed for comparison across all 30 countries included in the sample. Based on this comparison, it was noted that Japan, Estonia, and the United States had relatively high API scores. This suggested that because of a relatively high level of education, the NH and NDR awareness were similarly positive. In general, countries within Europe illustrated a relatively high API, whilst countries in Asia exhibited a relatively low API with countries from the Americas either high or low. Students in Japan, a country with a relatively high API (268.8) was, in general, expected to reach the highest level for test data on responsible behavioral actions, as indicated in Figure 1 and Figure 2 (chapter 3). Thus, a high API was expected to correlate with a strong achievement of students in school. Students in school through earth science teaching were thus expected to aspire to appreciate RBA and show an understanding of the supportive learning components.

Table 5. The country-specific values for Awareness and Preparedness Index (API) and its components (Awareness and Preparedness Factors). API = Awareness X Preparedness. See Fig. 3 for correlation between the factors.

#	Country	Awareness × 100	Preparedness × 100	API Value
1	Singapore	3.2	100.0	320.0
2	Finland	3.1	94.7	293.6
3	Japan	2.8	96.0	268.8
4	France	2.9	89.4	259.3
5	Slovenia	2.8	92.0	257.6
6	Spain	2.9	87.6	254.0
7	Canada	2.7	94.0	253.8
8	Belgium	2.8	90.5	253.4
9	Ireland	2.7	90.0	243.0
10	Estonia	2.5	96.1	240.2
11	United States	2.6	91.1	236.8
12	Czech Republic	2.6	90.1	234.2
13	Portugal	2.5	89.2	223.0
14	Lithuania	2.4	87.4	209.8
15	Slovak Republic	2.3	84.2	193.6
16	Chile	2.4	80.5	193.2
17	Serbia	2.4	79.8	191.5
18	Cyprus	2.1	79.6	167.1
19	Costa Rica	2.2	75.4	165.8
20	Brunei Darussalam	2.1	78.2	164.2
21	Romania	2.0	77.3	154.6
22	Mexico	1.9	76.0	144.4
23	North Macedonia	1.9	74.9	142.3
24	Brazil	1.9	73.3	139.2
25	Kazakhstan	1.9	72.0	136.8
26	Panama	2.0	66.2	132.4
27	Peru	1.8	73.3	131.9
28	Georgia	1.8	69.5	125.1
29	Indonesia	1.6	71.8	114.9
30	Philippines	1.6	64.7	103.5

5.2 Student Test Outcomes

Based on the model (figure 2), the test was administered to determine the relationship between student response patterns on Items perceived to relate to students' understanding of NOS, NOT and dispositions (categories 2A/2B), and their association with the model potentially impacting on the promotion of responsible behavioral actions, all within the event of a natural hazard.

An initial pilot study was devised with data collection undertaken in Estonia and the US in Spring 2015, with a view towards determining the suitability of the student test and thus increasing the validity and reliability of the devised instrument. The pilot study was as described in [P1].

Based on the pilot study outcomes, data through a meaningfully designed student test were collected in 5 categories, involving samples of students from three countries (Estonia, United States and Japan) and related to two grade levels (basic and advanced).

Category 1 – Personal Experiences with selected Natural Hazards

To determine whether student experiences of natural hazards played a role in the learning about responsible behavioral action in the case of natural hazards, a category in the student test asked information pertaining to experiences with natural hazards with a view towards comparing experience against responses to Items in categories 2 through 5. A further reason why personal experiences were included in the student test was to assess the impact of personal experience on other areas of learning with respect to the learning model portrayed in Figure 1.

Students were asked to indicate their personal experiences (as a Yes-No response) of four different natural hazards i.e. with respect to Hurricanes, Lightning Strikes, Earthquakes, or Tsunamis so as to assess students' experiences across both tectonic and meteorological natural hazards. Results were given in [P3, Table 8] and presented in a chart format in Figure 4.

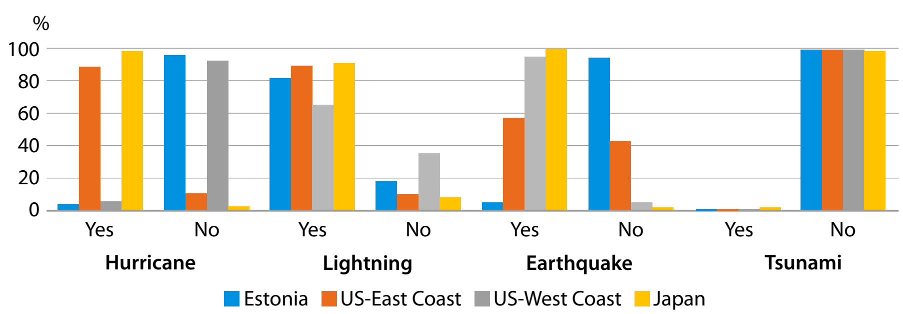


Figure 4. Student experiences (%) with respect to the selected 4 natural hazards

The chart showed that the majority of students indicated that they had experienced lightning, while the reverse seemed to be true for tsunamis (less than 5% of students experienced). There seemed to be strong differences between experiences of students on the US East and West Coasts. On the US West Coast, it seemed that the majority of students had experienced earthquakes, while few students on the US West Coast had experienced a hurricane. The majority of students from all samples indicated that they had not experienced a tsunami. Student experience with natural hazards was asked with a view towards exploring the relationship between experience with natural hazards and all other aspects of learning in the student test was addressed in later categories.

Student Comprehension of Nature of Science (NOS), Nature of Technology (NOT) and Dispositions, in the Context of Natural Hazards.

To determine student responses to Items 1–13 in category 2 of the test, each of the test Items were asked in one of two different formats, either an unaided response Item (in Version A), or a guided response Item expressed as a multiple-choice option (in Version B). The results were as given in the Appendix (Appendix 2a–2h). Interpretation of these results given below were related to each country/region in the corresponding appendix tables.

Overall, the mean scores in the test were low for the Items intended to relate to testing students' conceptualization of NOS (Items 1A–5B) and conceptualization of NOT (Items 6A–9A), but generally higher for Items (10A–13B), seeking to test student dispositions towards the learning of natural hazard disaster reduction (NDR). However, mean scores per a specific Item differed across countries/regions, at both the basic and advanced levels. This was to be expected as responses are predicted to be dependent on the degree to which the topic is taught, as well as on student differences. Also, no student was asked to answer more than 10 of the 25 Items and thus students responded to different sets of Items, each potentially differing in complexity, or perception. This inevitably affected mean scores for the different sub-sections.

To give a more detailed insight into test Item responses for category 2 and to allow further examination of learning associated with NOS, NOT and the gaining of dispositions, the mean scores were compared for Items common to the four different test Versions, per country/region.

Comparing Mean Scores for Items in the Different Test Versions per Country/Region at the Basic and Advanced Levels

A comparison of mean scores per common Item at both basic and advanced levels were indicated in Table 6. In the Table, N/A indicated at least one of the test Versions was not administered at that student level in the stated country/region.

Table 6. A comparison of mean scores for Items common in the different test Versions, per country/region, at the basic and advanced levels

		Common Test Items									
		Hurricane & Tsunami	**Lightning & Earthquake**			**Lightning & Tsunami**			**Earthquake & Tsunami**		
Item		3A	1A	6B	11A	4A	5A	12B	2A	9A	10B
Mean • Basic • Level	N	145	227	227	227	187	187	187	176	176	176
	Estonia	0.51 0.74	0.29 0.37	0.19 0.69	0.11 0.75	0.21 0.53	0.78 0.60	0.19 0.81	0.01 0.84	0.26 0.28	0.82 0.24
	N	N/A	241	N/A	241	N/A	N/A	119	122	122	N/A
	US East Coast	N/A N/A	0.42 0.35	N/A N/A	0.70 N/A	N/A N/A	N/A N/A	0.38 N/A	0.07 N/A	0.50 N/A	N/A N/A
	N	31	61	43	40	38	38	38	27	27	27
	US West Coast	0.52 N/A	0.08 0.04	0.46 0.58	0.38 0.04	0.21 N/A	0.11 N/A	0.68 N/A	0.85 N/A	0.34 N/A	0.83 N/A
	N	N/A	N/A	N/A	N/A	108	N/A	N/A	N/A	76	N/A
	Japan	N/A N/A	N/A N/A	N/A N/A	N/A N/A	N/A 0.34	N/A N/A	N/A N/A	N/A N/A	0.17 N/A	N/A N/A
Mean • Advanced • Level	N	160	104	104	104	108	108	108	116	116	116
	Estonia	0.03 0.03	0.21 0.16	0.35 0.41	0.46 0.84	0.58 0.15	0.73 0.80	0.96 0.98	0.84 0.02	0.38 0.00	0.80 0.22
	N	208	N/A	N/A	N/A	103	103	103	103	103	N/A
	US East Coast	0.06 0.06	N/A N/A	N/A N/A	N/A N/A	N/A 0.07	N/A 0.89	N/A 0.97	N/A 0.04	N/A 0.02	N/A N/A
	N	119	158	158	158	172	172	172	155	155	155
	US West Coast	0.85 0.85	0.24 0.31	0.47 N/A	0.08 N/A	0.30 0.78	0.08 0.04	0.47 0.88	0.84 0.85	0.50 0.55	0.00 N/A
	N	N/A	N/A	N/A	N/A	140	N/A	N/A	N/A	N/A	N/A
	Japan	N/A N/A	N/A N/A	N/A N/A	N/A N/A	N/A 0.82	N/A N/A	N/A N/A	N/A N/A	N/A N/A	N/A N/A

Key: N – Number of students tested
N/A No applicable data

In general, mean scores per Item showed a wide range from a mean of 0.00, or close to this, to a mean of almost 1.00, in all three countries/regions. This pointed to much uncertainty in student responses and suggested the students were very unfamiliar with the content of the questions and were likely to be guessing, or found the question very trivial (high mean scores), or, unfortunately, many students may decide, especially for the A Version, not to attempt a response. This raised the question as to the level of student motivation to respond, a suggested issue in seeking student data, which is relatively unfamiliar to the teacher who is asked to administer the test.

In line with the overall comment, the data gathered from basic level students varied between Items and test Versions. Generally, mean scores were low, but with exceptions e.g. responses to Item 5A. This pattern repeats itself for the advanced level, but again with exceptions e.g. Items 2A and 3A (from the testing in the US West Coast). The large disparity in responses was seen between scores and the degree of diversity by students at the basic level and those at the advanced level.

In general, there was little evidence of progression of learning indicated in the basic and advanced school student responses, although, for example, Items 6B and 12B, pointed to there being potential for-progression where Items are more familiar through exposure to teaching and learning. By reflecting on responses to Versions A and B of the Items, it was predicted that students were better able to make an educated guess when dealing with multiple choice responses (Version B) over the need to supply a response Item (Version A), and this often led to higher Version B means.

Determining Correlations between Components Deemed to be Associated with NOS, NOT and Disposition Items

The test data was examined from the different countries/regions, involving test outcomes per Items expected to be comparable with each of the three different, intended sub-divisions, referred to as NOS-*related* (Items 1–5), NOT-*related* (Items 6–9) and Dispositions-*related* (Items 10–13), where data was obtained from the same students. For this, Spearman's correlation coefficients were determined, allowing a comparison of responses with respect to selected Items, as indicated in Table 7. In the Table, only significant correlations for data from A Version Items were given at the basic and advanced levels. Data from B Items were not included as such comparisons were limited by the infrequency of asking B Items to the same students within the different test Versions.

Table 7. Spearman's correlation coefficients between responses re-NOS, NOT and Dispositions for Version A test Items

Sub component	Teaching level	Test Version	No of students	Items		Correlation
NOS-*related*	Basic	Tsunami	218	2A	3A	.576**
		Tsunami	218	2A	4A	.427**
	Advanced	Tsunami	316	2A	3A	.662**
		Hurricane	381	3A	4A	.427**
		Earthquake	292	1A	5A	.148*
NOT-*related*	Basic	Earthquake	257	6A	7A	.103
	Advanced	Earthquake	126	6B	9A	.433**
DIS-POSITION-*related*	Basic	Hurricane	242	10A	12A	.260**
		Earthquake	242	10A	13A	.309*
		Lightning	626	12A	13A	.106**
	Advanced	Tsunami	347	10A	12A	.146*
		Lightning	347	10A	13A	.266**

** Significant at the 0.01 level
* Significant at the 0.05 level

Although not specifically indicated in the Table (students answered only a selection of Items and rarely more than two Items per sub-division), the data suggested that there was, potentially, a significant correlation between Items 2A, 3A and 4A, at both Basic and Advanced levels. With respect to intended NOT related Items, the data seemed to suggest that there were no significant correlations between the Items included in the various test Versions. With respect to the intended dispositions-oriented Items, the data seemed to suggest that Items 10A, 12A and 13A exhibited significant correlations.

Undertaking Factor Analysis

To determine how well responses to test Items fit into factors associated with the intended indications of NOS and NOT conceptualization, as well as the development of positive dispositions, exploratory Factor Analysis (EFA) was undertaken. EFA was undertaken, separately, on each of the Hurricane, Lightning, Earthquake and Tsunami test Versions across the various student samples undertaking the same test Items**.** These samples varied in student numbers as not all countries/ regions tested each Version. Because of differences in test Versions given in Japan, factor analysis was undertaken separately. The outcomes from the analysis were as given in Table 8, by test Version. The Table illustrated indicated outcomes for a four factor Version, determining factors greater than 0.3 and involving all Items tested in each of the four subdivisions across the three countries/regions.

Table 8. Factor loadings associated with each of the hurricane, lightning, earthquake and tsunami test Versions for Estonia, US East Coast, US West Coast and separately for the differing Japanese Versions

Test Version	**Items**	**No. students**	**Factor Loadings**		
			1 –	**2 –**	**3 –**
Hurricane	1B	347			
	2B	347	.672		
	4A	347	.845		
	6A	347		.603	.523
	7A	480		.915	
	10A	347			.745
	12A	480			.399
	13A	480			.716
Lightning	1A	421		.850	
	3B	411	.522		
	4A	411	.721		
	5A	411			
	6B	412		.370	.595
	7B	411	.391		.412
	8A	510			
	11A	412	.336		
	12B	411			.768

Test Version	Items	No. students	Factor Loadings		
			1 –	2 –	3 –
	13B	411			.723
Earthquake	1A	383	.687		
	2A	383			
	5B	383	.315		
	6B	383		.339	
	8B	383		.600	
	9A	459			.785
	10B	383		.778	
	11A	383			.590
	12A	383	.775		
	13A	459			.585
Tsunami	1B	465	.826		
	2B	465	.837		
	4B	465	.757		
	6A	325			
	7A	465	.700		
	10A	325		.980	
	12A	456			
	13A	316			.984
Japan Hurricane	1A	142			
	2A	142	.951		
	7A	142		.993	
	12A	142			
	13A	142			.984
Japan Lightning	3A	99	.423		
	6A	99		.965	
	8A	99	.762		
	9A	99			
	11B	99			.893
Japan Earthquake	4A	67		.996	
	9A	76	.933		
	12A	67			.972
	13A	76			
Japan Tsunami	3A	149	.423		
	6A	140		.965	
	8A	140	.762		
	9A	140			
	11B	149			
	13A	149			.893

In the various test Versions, students only answered a few Items (usually 1–3 Items) in each sub-division. Although the student responses do not form a clear-cut sub-division, suggesting a level of unfamiliarity in the way the test Items were perceived, it seems that factor analysis gives indications that the Items intended to test learning within the sub-divisions tend to fit this pattern.

Factor 1 – NOS related

Table 8 showing consistent loading onto factor 1 were Items 2A (except in the earthquake Version), 2B, 3A, 3B, 4A and 4B, with less certainty for Items 1A, 1B and 5A and 5B. More specifically, in the hurricane test Version, both Items 2B and 4A loaded; in the lightning test Version, Items 1A, 3B and 4A loaded; in the earthquake test Version, Item 2A only weakly loaded into this factor whereas, in the tsunami test Version, Items 1B, 2B and 4B loaded into the factor, all associated with NOS related Items. For the Japanese data, where less Items were tested, the NOS related factors loaded into factor 1 for all test Versions, excluding earthquakes. There was an especially high loading factor for Item 2A.

Factor 2 – NOT related

Table 9 showed consistent loading onto factor 2 were Items 6A, 6B, 7A and 8B, with less certainty for Items 7B, 8A, 9A and 9B. In the lightning Version, the NOT related Item 7B, loaded on factor 2. For the lightning test Version, the B Version of Items 6 and 7 loaded into the same NOT related factor, while for the earthquake test Version, with respect to NOT, Items 6B, 8B and 9A loaded into the same NOT related factor and for the tsunami test Version, Items 6A and 7A loaded into the same factor for the intended NOT sub-division. Item 8A loaded into the same factor in the Japan lightning test Version, while in the tsunami test Version for Japan, Item 6A loaded well into the NOT related factor.

Factor 3 – Dispositions

Consistently loading onto factor 3 were Items 10A, 11A, 12A, 13A and 13B with less certainty for Items 10B and 11B. For the hurricane test Version, Items 10A, 12A and 13A loaded into the same factor for dispositions-related Items. For the lightning test Version, Items 11A, 12B and 13B loaded into factor 3. For the earthquake test Version, Items 11A, 12A and 13A loaded into the same factor. Item 10B loaded into the 2nd factor (.778) for the Earthquake test Version, and suggested Item 10B as an area of weakness in student competence with respect to relatively strong disposition responses. Item 11B loaded into the 3rd factor, dispositions (.893), suggesting validity with respect to Item 11B loaded with factor 3. For the tsunami test Version, with respect to the intended dispositions sub-division, Items 12A and 13A loaded into the same factor, contributing to the validity of student test Items.

Category 3 Inter-relationship between Science and Technology

Student understanding of the inter-relationship between science and technology was tested (category 3 in the student test). Results were illustrated in [P3 (Table 10)], and presented in a chart format in Figure 5.

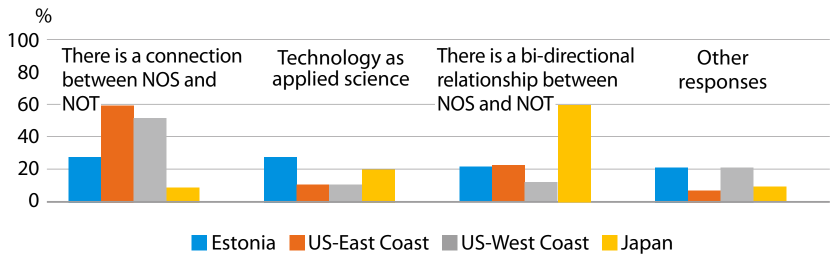


Figure 5. Student Responses Indicating Student Perceptions on the Relationship between Science and Technology

* There is a connection between NOS and NOT referred to students articulating that there is a connection between NOS and NOT, but it is other than bi-directional, or technology as applied science.
** Other responses referred to any other response outside of the other three response categories: "There is some connection"; "Technology as Applied Science"; or "Bi-Directional Relationship".

The chart showed that 60% students in the sample obtained from Japan recognized the bi-directional inter-relationship between science and technology while only around 25% students from the US East Coast and Estonia specified the bi-directional relationship. From analyzing the US West Coast data, the findings seemed to suggest few students meaningfully understood this relationship.

At the time of testing, there were no standards related to NOS and NOT in the Japanese Curricula (MEXT, 2009) and this suggested that Japanese students understood the bi-directional relationship between NOS and NOT via other means. Thus, Japanese students seemed to have an advantage and this is expected to be reflected in the student test results.
To determine whether there was a meaningful relationship between responses from categories 2 and 3, spearman's correlations were undertaken with a view towards determining significant correlations between category 2 category 3.

Table 9. Spearman's correlations between student responses from categories 2 and 3

Sample	**N**	**Spearman's Correlation Coefficient**
US East Coast	449	–.169**
US West Coast	373	–.051
Estonia	635	.144**
Japan	712	N/A

** Correlation is significant at the 0.01 level (2-tailed)

There seemed to be no connection between student test results from categories 2 and 3 with the exception of responses from Estonia, where a significant correlation of .144** was illustrated and on the US East Coast, there was a significant negative correlation of –.169**. Thus, there seemed to be no consistency between responses across the four samples.

Student Relative Perceptions of Danger towards selected Natural Hazards

Student perceptions of the perceived risks from natural hazards were tested (in the student test). Results showing student perception of the risks put forth by natural hazards were illustrated in [P3] (Table 11) and presented in a chart format in Figure 6.

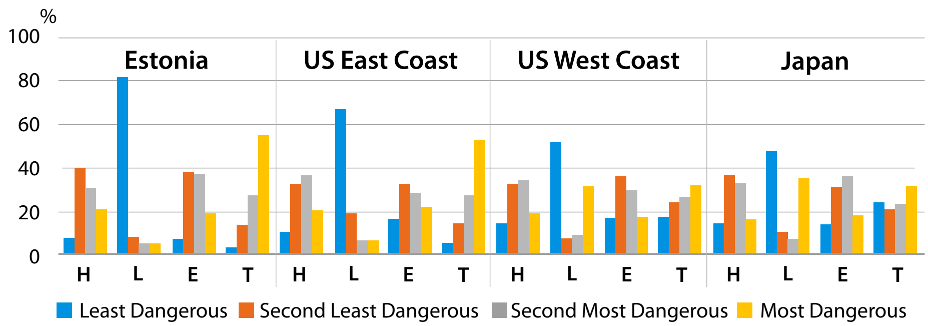


Figure 6. Relative percentage rankings of the perceived level of danger from Hurricanes (H), Lightning (L), Earthquakes (E) and Tsunamis (T)

Student perceptions of dangers associated with the 4 differing natural hazards were sought with a view towards identifying trends across all samples and to identify connections with experiences and learning related to the model in Figure 1. In general, students from all samples perceived that lightning was the least dangerous natural hazard and tsunamis were the most dangerous natural hazard.

Correspondence between Natural Hazards experienced and its comparable Natural Hazard perceived danger

The interrelationships between whether a natural hazard had been experienced and the level of the perceived danger for this natural hazard were determined (overall and per country/region) with a view towards examining the relationship between experience with natural hazards and perceived risks of natural hazards. The appropriate correlations were as indicated in Table 10.

As shown in Figure 6, students responded to category 4 by ranking Hurricane, Lightning, Earthquake or Tsunami risk perception by severity of their relative perceived danger from 1 (least risky) to 4 (most risky).

Category 4 Student perceptions of the danger posed by natural hazards

Responses of 1 or 2 (low perceived danger) recoded into 0 while responses of 3 or 4 (high perceived danger) were recoded as 1 for ease of comparison with results from categories 1, 2, 3 and 5. This comparison was undertaken with a view towards examining relationships between student test categories.

Table 10. Spearman's Correlation Coefficients between responses to natural hazard experiences and the corresponding students' responses to comparable perceived natural hazards

	Spearman's Correlations between Experience with and Perception of Natural Hazards								
Country /region		**Hurricane**		**Lightning**		**Earthquake**		**Tsunami**	
		Basic	**Advanced**	**Basic**	**Advanced**	**Basic**	**Advanced**	**Basic**	**Advanced**
US East Coast	Correlation	–.177**	.484**	.031	–.079	–.198**	.302**	– .030	.087
	Significance	.006	.000	.637	.258	.002	.000	.638	.211
	N	241	208	241	208	241	208	241	208
US West Coast	Correlation	–.067	–.06	–.083	.004	.204*	.013	N/A	–.077
	Significance	.514	.927	.421	.941	.046	.831	N/A	.199
	N	96	277	96	277	96	277	96	277
Estonia	Correlation	–.005	–.046	.132*	–.030	–.003	–.023	.035	–
	Significance	.922	.460	.011	.631	.951	.710	.497	–
	N	372	264	372	264	372	264	372	264
Japan	Correlation	–	–	–	–	–	–	–	–
	Significance	–	–	–	–	–	–	–	–
	N	283	429	283	429	283	429	283	429

* Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)

Category 4 results are omitted from table, because perception of the risks posed by natural hazards was omitted from the Japan test Version

Table 10 illustrated that there was little correlation between experience of natural hazards and perceived danger of natural hazards. Table 10 illustrated a significant correlation between US West Coast earthquake basic (.204*) but not at the advanced level whilst in Estonia basic lightning (.132*) illustrated a significant correlation, suggesting a link between experience and perception of risk with respect to natural hazards.

In case of student comparisons of experiences and perceived danger of Hurricanes, only US East Coast basic school students (.294**) illustrated a significant correlation between experience with natural hazards and behavioral action, suggesting that there is a lack of a meaningful connection between experience with natural hazards and behavioral action in the case of hurricanes.

There was a significant correlation between having no experience of a tsunami, but viewed tsunamis as dangerous.

Category 5 Behavioral Action with Respect to Selected Natural Hazards

In responding to Items in category 5, seeking behavioral actions in the case of a specific natural hazard, students utilized a map as illustrated in Appendix 3. Results were as illustrated in Table 11. Mean scores were given by country/region and hazard Version [P3, Table 3].

Table 11. Student mean percentage scores for behavioral action put forward related to action during a Hurricane, Lightning, Earthquake or Tsunami

Location	**Natural Hazards**							
	Hurricane		**Lightning**		**Earthquake**		**Tsunami**	
	N	%	N	%	N	%	N	%
US East Coast	449	74.3	449	54.6	449	40.2	449	63.1
US West Coast	373	53.8	373	41.6	373	42.9	288	54.1
Estonia	636	38.4	636	62.9	636	62.2	636	64.8
Japan	712	54.2	712	59.6	712	81.6	712	66.4

Results suggested that behavioral action responses by students were highest by percentage for those students who responded to test Items geared towards Tsunami and Hurricane behavioral action and behavioral action responses were lowest by percentage for Earthquake and Tsunami scenarios.

Comparing Experiences of Natural Hazards and scores in category 5 related to responsible behavior in the event of a corresponding natural hazard occurrence

In order to compare students' experiences with different natural hazards with corresponding behavioral action, Spearman's correlations were undertaken. Table 12 below gives correlations for each of the 4 countries/regions between students' experience of a specific Natural Hazard and the mean score obtained in category 5, related to the same natural hazard.

Table 12. Spearman's Correlations between experience with natural hazards and mean scores on items determining responsible behavioral action in the case of Hurricane, Lightning, Earthquake and Tsunami

Country/Region		**Hurricane**	**Lightning**	**Earthquake**	**Tsunami**
US East Coast	N	105	119	122	103
	Average	.180	.123	1.00	.076
US West Coast	N	65	125	97	N/A
	Average	.014	.079	1.00	N/A
Estonia	N	177	167	164	128
	Average	–.011	.040	.004	N/A
Japan	N	133	99	67	76
	Average	.027	–.098	.136	N/A

In general, there seemed to be a lack of a meaningful relationship between exposure to a natural hazard and the learning about natural hazards learning at school, i.e. everyday experiences seemingly show there was little relationship/impact on school learning.

Experience of Natural Hazards (category 1) and the Test (category 2) related to Comprehension of NOS, NOT as well as Attitudes toward Disposition

To determine whether there was a significant correlation between experience with and behavioral action during the event of a natural hazard, Spearman's correlations were used.

Table 13. Spearman's Correlations between experience with natural hazards and mean scores for category 2 responses.

	Experience with Hurricanes	**Experience with Lightning**	**Experience with Earthquake**	**Experience with Tsunamis**
US East Coast	.178** N=449	.055 N=449	.067 N=449	–.015 N=449
US West Coast	.009 N=373	.025 N=373	.103* N=373	0.80 N=373
Estonia	.020 N=636	–.037 N=636	.020 N=636	–.036 N=636
Japan	.043 N=712	–.006 N=712	.075* N=712	–.059 N=712

** Significant at the 0.01 level
* Significant at the 0.05 level

Table 13 showed that significant correlations between experience with natural hazards and mean scores of the test in category 2 related to comprehension of NOS, NOT and attitudes towards Dispositions were not identified.

Comparing mean scores from items on NOS, NOT and Disposition competences and the relationship between Science and Technology

The mean scores for category 2 responses were compared with responses to the perceived relationship between science and technology indicated in category 3 with a view towards identifying and analyzing relationships between student responses. Spearman's correlations between categories 1 and 2 were as illustrated in Table 14.

Table 14. Spearman's correlations between results average results for category 2 and category 3

Country	N	Spearman's Correlations between category 2 and 3 mean scores
US East Coast	449	–.047
US West Coast	373	.096
Estonia	636	.045
Japan	N/A	N/A

** Significant at the 0.01 level; * Significant at the 0.05 level

The data indicated that there seemed to be no significant correlations between results from category 2 and 3. This suggested that NOS and NOT and their interrelationship had not been taught.

Examining connections between student mean scores for category 2 testing NOS, NOT and Dispositions vs. 4. Indicating students Perceptions of the risks posed by Natural Hazards

Results from the mean scores on the student test from NOS, NOT and dispositions Items were compared with results from risk perceptions for natural hazards for each of the four sampled locations. The results were as illustrated in Table 15.

Table 15. Spearman's Correlations between student responses to category 2 and category 4 by sample and type of natural hazard

Country	Spearman's Correlation Coefficient– category 2 (NOS, NOT, Dispositions) against category 4 (Experience with Natural Hazards)			
	Hurricane	Lightning	Earthquake	Tsunami
US East Coast	–.108* N=449	–.055 N=449	–.099* N=449	–.109* N=449
US West Coast	–.095 N=373	–.009 N=373	–.070 N=373	–.041 N=373
Estonia	.111** N=636	.057 N=636	.066 N=636	.118** N=636
Japan	.022 N=712	.219** N=712	.023 N=712	–.189** N=712

** Significant at the 0.01 level; * Significant at the 0.05 level

The findings indicated in Table 15 comparing outcomes from the student test for categories 2 and 4 seemed to indicate that, in general, there was a lack of a meaningful correlation.

Comparing results from the student test from Category 2 against Category 5 via Spearman's Correlations

Average scores for the sum of the test Items related to NOS, NOT and Dispositions were compared with behavioral action average scores for Items that sought behavioral action responses to specific natural hazards to analyze their relationship. Spearman's correlation coefficients were determined, as illustrated in Table 16.

Table 16. Spearman's Correlation coefficients for Items in categories 2 and 5

Mean Category 2 scores versus Mean Category 5 Scores		
Country/Sample	**N**	**Spearman's Correlation Coefficient**
US East Coast	449	–.085
US West Coast	373	–.046
Estonia	628	–.018
Japan	712	.050

There seemed to be no significant correlation between results. This suggested that meaningful acquisition of teaching and learning NOS/NOT as a development towards being able to put forward behavioral action with respect to a natural hazard situation was not taking place.

5.3 Teacher Preparedness and Attitudes toward Teaching NH and NDR

Teacher data had been gathered to complement student data in two, but interconnected, ways. First, teacher responses were solicited to a questionnaire, seeking to determine teacher conceptualization and dispositions towards teaching and learning NDR attributes i.e. NOS, NOT, NH in NGSS and RBA. Second, these responses were checked for commonality in line with that seen as generally intended, through individual interviews with a small, but carefully selected, group of teachers, familiar with the intended teaching emphasis within the teaching of NDR.

The questionnaire was administered to 35 teachers (10 teaching at the basic level and 25 at both the basic and advanced level) and the corresponding teacher responses, arranged in 5 Components covering Items 1–19, were as given in Table 17. The teacher interview questionnaire was devised and validated by modifications based on feedback from expert opinion (science teachers and two science education professors).

Table 17. Teacher Responses to the Questionnaire

Category	**Question**	**Outcomes and Comments**	**Number of Agreeable Responses**	
			Basic N=10	**Advanced N=25**
1	1	*Do you include natural hazards in teaching?*	N=10	N=25
	2	*Indicate whether teaching at High School (advanced grades 9–12) level, or Middle School (basic grades 6–8);*	N=10	N=25
2	3	*Teachers report that teaching/learning NOS involved:*		
		(a) Students gaining information and conceptualization;	N=9	N=17
		(b) Fostering student creativity;	N=8	N=18
		(c) Students determining solutions to scientific problems or making observations based on evidence;	N=10	N=24
	4	*Teachers reported that it is important to teach:*		
		(a) distinguish between a scientific law and a scientific theory;	N=6	N=14
		(b) be creative and show imagination;	N=9	N=15
		(c) carry out observations based on real-world evidence;	N=10	N=25
	5	*Teachers reported that teaching/learning NOT involved:*		
		(a) Technology is only technology if it is seen as useful;	N=4	N=5
		(b) A useful technological process needs to be creative and innovative;	N=6	N=17
		(c) Technology is only accepted as a technology if it is perceived as an improvement on that existing.	N=7	N=6
	6	*Teachers reported that it is important to teach:*		
		(a) Technology is only technology if it is seen as useful);	N=2	N=7
		(b) A useful technological process needs to be creative and innovative;	N=8	N=15
		(c) Technology is only accepted as a technology if perceived as an improvement on that existing.	N=5	N=5
	7	*Do you feel that teaching about the bidirectional relationship between science and technology is important, with respect to natural disaster reduction?*	N=10	N=21

Category	Question	Outcomes and Comments	Number of Agree-able Responses	
			Basic N=10	**Advanced N=25**
3	8	*Are you familiar with Next Generation Science Standards (NGSS)?* *If not, please skip ahead to question 12.*	N=10	N=21
	9	*Do you consider the following excerpt, taken from NGSS, are important areas for learning? "Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans. Examples of solutions could include designing an earthquake resistant building and improving monitoring of volcanic activity"; [Re NRC, 2012; 4-ESS3-2].*	N=10	N=20
	10	*Do you consider the following excerpt, taken from NGSS, are important areas for learning? Different severe weather conditions are more likely than others in a given region. Weather scientists forecast severe weather so that the communities can prepare for and respond to these events. "Ask (students) questions to obtain information about the purpose of weather forecasting to prepare for, and respond to, severe weather" [Re NRC, 2012 – K-ESS3-2].*	N=10	N=20
	11	*Do you feel you are adequately promoting the Next Generation Science Standards (NGSS) with respect to supporting student learning related to natural hazards and associated disaster reduction?*	N=10	N=21
	12	*The frequency and magnitude of natural hazards in our lives has been increasing. In your view, how important is it to include teaching about natural hazards and ways to reduce risks posed by natural disasters (in high school)?*	N=10	N=25
	13	*Do you believe it is important for students to be guided by teachers to learn how to act responsibly during a natural hazard in a way that reduces risks and saves lives?*	N=10	N=24

Category	Question	Outcomes and Comments	Number of Agree-able Responses	
			Basic N=10	Advanced N=25
4	14	*Imagine the national weather service has just issued a hurricane evacuation warning for your area. With respect to this situation, would you want students, based on your prior teaching, to be able to take specific actions with a view towards promoting natural disaster reduction?*	N=10	N=25
	15	*Do you agree that the diagram (Figure 2) can provide an effective frame for teaching natural hazard competences (knowledge, skills and values/attitudes) about natural hazards when also considering natural disaster reduction?*	N=10	N=24
	16	*Should students, in your opinion, be able to put forward suggested actions (RBA) to take in the case of a specific natural hazard?*	N=10	N=25
	17	*It is proposed that to act responsibly (take responsible behavioral actions) in the event of a natural hazard requires cognitive ability. Therefore, do you agree that there is a need to approach the teaching of natural hazards so as to enhance both science knowledge and skills?*	N=10	N=25
	18	*Do you feel it is reasonable to expect students to be able to put forward responsible actions in case of a natural disaster, even in an entirely new situation, unfamiliar to the students?*	N=10	N=24
	19	*Do you agree that the scenario suggests an appropriate context through which to teach about natural disaster reduction (in this case a tsunami)?*	N=8	N=17

Key N/A – Not applicable

Table 17 illustrated that overall teacher responses, at both the basic and advanced teaching levels, were comparable and can be seen to correlate with each other. It was noteworthy that basic level teachers were very strongly in agreement with Items 7–19, but for some of these Items there was more ambiguity for advanced level teachers.

Teacher responses (both for those teaching at the basic and the advanced levels) to Items 3 and 4 (related to an understanding and the teaching of NOS) were rather disappointing, except for part c, which related to evidence, and suggested that the evidence-based aspect of NOS was well understood. Nevertheless, these agreements were higher by percentage than for the NOT-related Items (Items 5 and 6), where the number of agreement responses, especially with respect to advanced school teachers, were much lower. It seemed, based on results from Items 3–6 that the inter-relationship between NOS and NOT was poorly understood by the teachers, although rather surprisingly most teachers responded positively to Item 7 i.e. understanding the bi-directional relationship between NOS and NOT. It was speculated that perhaps advanced level teachers did not see the need to teach about the bidirectional nature as it was taught at the basic level.

Teacher responses to the Items indicated a familiarity with NGSS and its intentions (Items 8–11). The responses were very positive, for both basic and advanced level teachers. Positive responses were also given for teacher views with respect to the teaching and learning aspects of natural hazards (Items 12–14).

It was interesting that teachers were generally in agreement on the need to teach about NDR (Items 15–18) This was encouraging because it suggests teachers hold positive views and thus do not require substantial improvement/ development with respect to (attitudes and values towards NDR). Teachers felt that the teaching and learning of responsible behavior action is an important aspect to promote and their views based on responses to Items 15–18 in the teacher survey.

For Item 19, it seemed that teachers generally agreed that teaching about natural hazards through a scenario approach was seen as appropriate and useful at both basic and advanced levels, although agreement was not unanimous.

5.4 Teacher Interview Responses

To collaborate the teachers' views given in the questionnaire stated in Table 3 [P3 – Table 10], an additional group of six teachers, identified as familiar with NGSS and the teaching of earth science topics including natural hazards, were interviewed separately.

The overall summary of consensus responses by the interviewed teachers (obtained, where necessary, using secondary questions) were as put forward in Table 18. Noting the rationale for interviewing the six teachers was not to seek answers to the questions in the teacher questionnaire per se, but to clarify any confusion given by the teachers responding to the questionnaire, this clarification was organized by comparing the responses to the questionnaire and the interview. These five questions were of value when making comparisons with questionnaire Items to gain insights and perspectives to teacher dispositions with respect to teaching NOS, NOT and NDR.

Table 18. Teacher Responses to the interview

Category	Question	Collaborative comments put forward by the interviewees
1 NOS	What do you understand by NOS and how do you rate its importance?	With guidance from asking subsidiary questions, all interviewees indicate that teachers need to appreciate the nature of science such that they can guide students to be creative and imaginative (putting forward ideas), this being important in taking action in NDR situations, needing to relate to scientific laws, based on observation and scientific evidence.
2 NOT	How important is it for students to be guided to be able to foster technological ideas?	Appreciating that in NDR situations innovative and creative technology is invaluable, if this is an improvement on the prior situation. Thus, teachers need to foster students' technological ideas in seeking scientific solutions to problems.
3 NGSS	How familiar are you with NGSS and its intentions?	All interviewed teachers indicate they are familiar with NGSS and see NGSS as more conceptual, seeking critical thinking, model based, and phenomena related to earlier science curricula. These teachers specifically mention that NGSS encompasses cross cutting concepts, such as problem solving, decision making and communication.
4 NDR	What is your interpretation of coverage of NDR within NGSS?	While the interviewees draw attention to the reference to Natural Hazards (NH) in NGSS, they are able to recognize that NGSS encompasses few, if any, relevant standards related to NDR. On seeking further detail, they indicate that this is insufficient and more attention needs to be placed on NDR situations within NGSS. Student outcomes related to the questionnaire were a result of teachers placing an insufficient amount of attention to NDR.
5 RBA	How suitable are the behavioral actions proposed for teaching NDR?	All interviewees appreciate the behavioral action approach, put forward in teaching NDR, in both meteorological and geological situations. They appreciate that behavioral action is based on conceptual scientific thinking. They further indicate that the example of an approach in Figures 1 and 2 are likely to be meaningful to students and should be seen by teachers as an effective way of teaching if made sufficiently relevant.

In general, the responses from the six interviewed teachers were meaningful, because each of the interviewees responded in a similar manner, giving validity to the intended viewpoints and expectations which was used in interpreting the responses in the teacher questionnaire especially where there was diversity. Teacher interview responses provided valuable comments/insights to complement responses to the teacher questionnaire, highlighting discrepancies in responses to the teacher questionnaire. With respect to comments/insights by the interviewed teachers in the USA, and, overall, by the teachers responding to the questionnaire, both teaching at the basic and advanced levels, there was general agreement that developing student competences with respect to NOS, NOT, dispositions for learning about natural hazards (NH) and undertaking responsible behavioral action (based on teacher questionnaire responses to Items 1–19) was important when teaching and learning about NH/NDR in school based on responses from the student test and teacher interview.

It was felt that the interviewed teachers, from their response to questions 1 and 2, showed a good grasp of the meaning attributed to NOS and NOT, enabling them to point to the weak agreement among teachers in responding to questionnaire Items (3–6) giving an indication as to possible reasons (such as lack of sufficient teacher competences for NOT and NOT) for the generally poor responses by students in giving answers to the NOS and NOT related Items in the student test (category 2).

Teachers generally felt that NGSS standards encompassing NGSS were useful and appropriate. It seemed that teachers felt that NGSS standards could go further towards including RBA in future Versions.

6. DISCUSSION

This thesis investigates the role of education, and science education in particular, in the promotion of natural hazard awareness and preparedness for teaching natural disaster reduction, as well as the teaching/learning of responsible behavior actions during a natural hazard event. This is based on an appreciation of the nature of science and also the nature of technology, plus the progressive development of dispositions. The thesis involves:

- identification of a country's focus on the role of education in increasing an awareness of, and reducing the impact of, natural hazards by the development of a country-related index. This index is put forward with a view towards providing a measure of the potential role that education, and science education in particular, plays through the developed index, in impacting on a country's vulnerability versus education interrelation, above and beyond that indicated in a World Risk Index (UNU, 2016). A major modification is the development of a perceived, more meaningful, awareness and preparedness index (API);
- the devising and use of an inter-related theoretical and teaching model by highlighting a progression in the development of NOS (McComas, 1998; Lederman 2007; Fernandes, Rodrigues, & Ferreira, 2017), NOT (Constantinou et al., 2010) and dispositions (OECD, 2019). This is undertaken through putting forward cross cutting, conceptual educational levels, with the purpose of promoting responsible behavioral actions [P1]. The model further puts forward an educational approach to facilitate conceptualization and operationalization of a meaningful approach to natural disaster reduction measures. A major modification of the model beyond the Version in [P1] specifically relates to separating the theoretical underpinning from the teaching and learning approach, both leading to the taking of responsible behavioral action during, or after, a natural disaster event;
- a developed and validated student instrument, based on the theoretical and teaching components of a model, to ascertain the degree to which current teaching determines students' acquisition of NOS (McComas, 1998; Lederman 2007; Hodson & Wong, 2017; Fernandes, Rodrigues, & Ferreira, 2017), NOT (Constantinou et al., 2010), dispositions (OECD, 2019) and responsible behavioral action (Sims & Baumann, 1983) attributes in three countries with respect to taking actions towards natural disaster reduction. The instrument is applied in four country or regional settings, differing in exposure to natural hazards, as put forward in category 2 in [P3];
- devising and administering a teacher questionnaire seeking earth science teacher perceptions. opinions and level of incorporation of NOS (McComas, 1998; Lederman 2007; Hodson & Wong, 2017; Fernandes, Rodrigues, & Ferreira, 2017), NOT (Constantinou et al., 2010) and dispositions (OECD, 2019) components in their teaching in line with the devised model. The

questionnaire seeks to determine the teaching rationale driving students' learning with respect to natural hazards and taking responsible behavioral actions, thus promoting students to take responsible behavioral action for disaster reduction when faced with an occurrence of a natural hazard.

6.1 A Countrywide Natural Disaster Reduction Index

Mitigating against natural hazard (NH) risks (see chapter 1) was seen as an important educational goal. While the World Risk Index (WRI) (UNU, 2016) was associated with risk, the article [P2] sought a vulnerability-education interrelation indicator/index, building on a country's vulnerability towards natural hazards and to derived an indicator/index related to the potential impact of an education factor. This differed from WRI (ibid) in that it sought to show that formal education was a key factor in dealing with natural hazard disaster reduction (NDR). The [P2] indicator used an education factor, based on the PISA 2018 (OECD, 2019) science data per country, arguing this to be a meaningful education indicator to associate with a derived natural hazard vulnerability indicator so as to establish a 'vulnerability to natural hazards versus education' indicator/index (NDF-EF). The [P2] article showed the impact of education related to attributes associated with NDR was derived [P2] across 15 countries and especially for the three countries where this thesis sought to determine the level of students' learning, associated with natural hazards and responsible behavioral action in the case of a disaster.

As a modification, an awareness and preparedness index (API), as derived in this thesis, was a more valuable index, irrespective of the differences in the sources of potential risks posed by natural hazards across the country. Such a countrywide index was argued to be meaningful in a small country, such as Estonia, especially as the population exposure to natural hazards was relatively uniform. But in a large country, such as the United States, the potential exposure varies enormously from region to region. Nevertheless, in today's age of ease of cross-country and international travel in conjunction with a recognized increase in frequency and magnitude of meteorological natural hazards (Emrich & Cutter, 2011; Li et al., 2019), the ability to move from region to region or even country to country means that a 'countrywide awareness and preparedness' index was able to be taken as a meaningful indicator. As such, the API was seen as having greater value than a derived NHF-EF index [P2], being based on the relationship between awareness and preparedness, two variables seen as under the control/ autonomy of humans, whereas this was not always the case with respect to vulnerability as an overall entity. The API was thus seen as a valid and reliable approach towards illustrating the relationship between preparedness and awareness between select countries in Asia, Europe and the Americas. Further, it enabled pivoting away from risk and towards awareness and preparedness, which was more clearly associated with science teaching and teaching NDR through real world experiences as well as everyday contexts relevant to students. Through the API, the relationships between natural hazard factors and the value of education were interrelated, increasing the validity of the API through lines of regression calculated for the relationships, which showed a strong, positive relationship between education and the combination of the lack of coping and adaptive capacities. The calculated index, established for 30 countries, showed that while Estonia and the US were similarly placed, the index for Japan was somewhat higher, indicating that Japan was relatively more aware and prepared in dealing with natural hazards. Preparedness is the key educational term and hence this is the importance of having an index that takes strong note of education. Awareness is the ability to make forced-choice decisions above a chance level of performance. Awareness is associated with LoC and LoA in that awareness is a precursor to an ability to cape or adapt during a natural hazard situation.

6.2 A Teaching-Learning Model

In undertaking this research study, it was recognized that devising a 2-component model – one version referring to the theoretical and the other teaching oriented, was needed. While curricula, such as NGSS (NRC, 2012), provided both content and cross cutting skills, a model was seen as important to guide the teaching of NH and NDR and enabling teachers to put curriculum theoretical ideas side by side with a meaningful teaching approach, based on a learning progression. The model was designed to address earth science learning conceptualizations and be operationalized through a hierarchical, 4-level teaching approach.

The model was seen as a major step forward, as earlier models (Maslow, 1943; Vygotsky, 1978) placed an insufficient emphasis on actions to take during the event of a natural hazard. For example, in NGSS, the only standard that related to behavioral action was put forward as follows:

> "Ask questions to obtain information about the purpose of weather forecasting to prepare for, and respond to, severe weather" (NGSS, 2013, pp. 7).

The aforementioned reference was insufficient because there was a lack of NGSS coverage related to behavioral action in the event of a lightning strike, earthquake or tsunami. Thus, NGSS required more explicit text related to natural hazard disaster reduction (NDR), plus being a guide to practical teaching linked to NH/NDR. The model developed in [P1], although not solely intended to be specific to the content of natural hazards, was seen as sufficiently broad to serve as a theoretical educational frame. Furthermore, using the Figure 2 teaching/learning progression, the model was able to focus on the manner in which teachers support student learning related to NH and NDR, seeing the teaching/learning emphasis develop through four progression levels as students acquired higher level thinking abilities (Piaget, 1971). Thus, while the model put forward in [P1] was developed as a meaningful step forward, particularly in a theoretical context the addition to the model, put forward in Figure 2, was seen as enabling more specific guidance towards the teaching/learning progression, not only for promoting NH/NDR, but science education in general.

Figure 1, as put forward in [P1], was devised as an initial model for promoting teaching/learning conceptualizations within science education, based on a perceived lack of a suitable taxonomy by which to guide teaching and learning with respect to Natural Hazards (NH) and Natural Disaster Reduction (NDR). The taxonomy was strongly based on Bloom's taxonomy (1956) and cross-cutting skills (NGSS, 2013; P21, 2008) with the goal of developing students' self-actualization (Maslow, 1943). The model purposely included recognition of the importance of an appreciation of NOS (McComas, 1998; Lederman, 2007), as well as an appreciation of NOT (Constantinou et al., 2010) and thus the model went beyond the subject-related domain and incorporated cognition associated with the meaning or nature of both science and technology and also sought to pay attention to the importance of dispositions (Claxton & Carr, 2004; Carroll, 2012). But building on the conceptualization and seeing the target as the need for self-actualization, the model went beyond problem solving (Rotherham & Willingham, 2010; Pellegrino, 2012) and even decision making (Holbrook & Rannikmäe, 2010; Holbrook & Rannikmäe, 2014).

Teaching, associated with the model illustrated by Figure 2, was related to guiding students to interact, as a first step, with contextual scenarios, recognized in the three level teaching approach (Holbrook & Rannikmäe, 2010) as a motivation level, plus the need to determine students' prior learning. The teaching then moves to also include a decontextualized, second level to promote new subject learning with respect to science conceptual gains, plus personal educational competence development, thus showing the progression was designed to include cognition, the nature of science and technology, as well as attention to student attitudes and dispositions through active, student involved, learning. The value of the second level was to enable teachers to see that the teaching was not independent of a theoretical underpinning concern. This was seen as important, noting a concern in science teaching that teachers relate to the content and the teaching method, but tended to ignore the theoretical basis for the learning (Tytler, 2007).

Where students were at a memorization level (lowest Bloom taxonomy level) (Bloom, 1956), the teaching-learning was mostly at level 1 in Figures 1 and 2. When students had developed intellectually so as to be able to handle conceptual learning, problem solving was expected to be practiced, both in thinking and procedurally (practical). Figure 2 thus placed an emphasis on competences to develop in the teaching progression in particular with respect to the levels (familiarity motivation, problem solving and decision-making levels), within a natural hazard context. Nevertheless, promoting responsible behavioral action was the goal for the model and was thus positioned in the apex position in Figure 2. Importantly, Figure 2 proposed an approach to teaching which built up through a teaching and learning progression approach, founded on a constructivism learning approach (Bruner, 1960; Piaget, 1971; Vygotsky, 1978), as described in chapter 3. The socio-scientific, decision making level (level 3 in Figure 2) involved the need for developing argumentation skills and the need to put forward a consensus, meaningful science–based decision that related to the concerns in an initial, natural hazard scenario.

The teaching model in Figure 2 was especially designed to promote greater attention to undertaking responsible behavioral action and hence greater coping capacity and lower susceptibility to natural hazards. For this, the model added a 4^{th} level beyond the literature-based, 3 level model (Holbrook & Rannikmäe, 2010). This level, was seen as aligning with self-actualization in Figure 1 (Maslow, 1943), stressed the need for creative thinking and for students to be able to put forward novel practical, yet science–based, responsible behavioral action in a given disaster situation.

6.3 Student Achievement, Determined against Attributes of the Teaching/Learning Model

In general, student achievement across the entire student sample, identified against model attributes (Figure 1) towards the giving of natural hazard behavioral action responses, was shown to be weak (Table 11). This finding, applicable to all countries/regions, was generally similar across each of the natural hazard situations tested i.e. hurricane, lightning, earthquake and tsunami. This outcome pointed to a concern related to the focus and depth of treatment of teaching with respect to students' conceptualization of natural hazard topics in the field of earth science, especially related to the model. With today's society facing increasing exposure to severe occurrences of natural hazards (Wisner et al., 2004), the development of responsible behavioral learning within science education was seen as being of increasing importance.

Of major importance, the outcomes seemed to particularly indicate that the capability to apply learning from the classroom to real situations e.g. to put forward behavioral actions in response to a natural hazard occurrence, were not being achieved. This implied a potential lack of teaching/learning attributes, particularly with respect to the important necessity of higher levels of cognition, as suggested by Zoller & Pushkin (2007). It was not surprising that student responses were much more positive, where the testing was based on lower cognitive levels of learning (e.g. at the informational and lower order problem solving levels, levels 1, and 2 (Zoller & Pushkin, 2007), as indicated at the lower levels in the model represented by Figure 2.

The test (devised and validated in P1) sought to determine students' experiences, the relative dangers, and how to take responsible behavioral action, when faced with natural hazards, as well as the level of achievement in attributes that contributed to behavioral action, as indicated in Figure 1. In particular, the test addressed comprehension of NOS, NOT, as well as dispositions towards the learning about natural hazards and the relationship between science and technology. These attributes were determined, related to one of the following natural hazards, namely: Hurricanes, Lightning, Earthquakes, or Tsunamis (two meteorological and two tectonic natural hazards). The test also sought students' experience (MOFA, 2020) with all these natural hazards, as well as the relative dangers with respect to each hazard with a view to determine whether experience had an impact on motivation to learn about NH and NDR.

The test comprised 5 separate categories, and where appropriate, related to one of the four allocated natural hazards selected, as indicated in the methodology.

Category 1 – Experiencing Natural Hazards

The category 1 findings, as shown in Figure 4 across each of the 4 countries/ regions, indicated that lightning was stated as the most frequently experienced natural hazard, while tsunamis were the least. However, in predicting whether experience of natural hazards could play a role in how students interacted with learning about natural hazards, no meaningful relationship was identified based on student responses. Research by Phillips & Schmidlin (2013) indicated that there was a lack of a significant connection between lightning safety knowledge and experience with lightning. Nevertheless, as students generally experience few of the natural hazards of major concern (especially tsunamis), with increased population mobility it was seen as important that the teaching in school guided students towards finding out more about how to react, or behave in the event of being involved with any natural hazard. Furthermore, while experiencing events, or situations, was known to be a valuable learning experience, it was clearly irresponsible to unnecessarily expose students to natural hazard situations. With this in mind, an important implication of these findings could be the introduction of simulation exercises, as shown in Appendix 3, enabling students to experience natural hazard situations, albeit as an artificial situation.

Category 2 – Appreciation of NOS, NOT and Student Dispositions toward the learning associated with Natural Hazards and NDR according to the model

The theoretical model devised in chapter 3 was developed, based on the literature supposition that an increasing appreciation of NOS and NOT were important components of science learning (McComas, 1998; Lederman, 2007) and needed to be strongly supported by the development of positive dispositions. Category 2 encompassed two different test Versions: Version A and Version B. (as explained in the methodology). Based on test outcomes across all student groups, it became evident that students did not adequately understand NOS, as illustrated in Table 8 given in [P3] and in Appendix 2a–2h, irrespective of version. This finding agreed with findings from other studies. Identification of the lack of student NOS understanding was clearly indicated by the poor responses to Item 1, related to one feature of NOS seeing scientific knowledge being tentative, yet durable (McComas, 1998; Lederman, 2007). Furthermore, the low percentage of correct responses in Table 8 given in [P3] suggested that students did not adequately understand that scientific knowledge was subject to revision in the light of new evidence, an important consensus aspect, pointed out in the literature (McComas, 1998; Lederman, 2007) associated with the nature of science. Of more concern, there was little difference in responses from students in the lower levels (grades 7–9) and the advanced groups (grades 10–12), which further implied a lack of teaching related to NOS and hence the model in figures 1 and 2.

Seeking to determine whether there was a connection between the responses to all 5 NOS Items, findings (Table 8) indicated a connection between Items 2, 3 and 4, where these Items loaded onto the same factor (Factor 1 – identified as an NOS-related Factor). Thus, it seemed that while Items 2, 3 and 4 inter-related (as illustrated in Table 8), Items 1 and 5 did not. This implied the need for focusing the teaching and learning more when addressing NOS with ways to relate this with respect to everyday life and promoting student ideas on undertaking responsible behavioral action. The current deficiency could perhaps be because textbooks might reinforce a misconception that there was a progression within science, from making an initial inference, based on a finding to subsequently formulating a theory then based on wide acceptance seeing this put forward as a law (McComas, 1998). An implication of this finding was the need to include, more explicitly, the distinction between a theory and a law in science curricula e.g. with respect to curricula-related documents, such as NGSS (NGSS, 2013), MEXT (MEXT, 2009) and the Estonian National Curriculum (Estonian Government, 2011), all of which, at the time of testing, had no such inclusion. Thus curricula need to be more explicit in indicating the key meanings associated with NOS.

Although Items 1 to 5 all tested conceptualization of the nature of science (NOS) (McComas, 1998; Lederman 2007; Fernandes, Rodrigues, & Ferreira, 2017), there was very little interconnection between student responses e.g. Items 1 and 2. This seemingly indicated that these Items were testing very different orientations of NOS. However, exploratory factor analysis undertaken on category 2 Items, answered by the groups responding to such incorporated Items in each country (Table 8), showed both Items 1 and 2 loaded onto the same factor (an NOS-related factor), where Item 1A (included in the earthquake test Version) and Item 1B (included in the tsunami test Version) both loaded onto the same NOS-related factor (Factor 1*)*.

For Item 2, it was found that the responses to Item 2A (in the Japanese Version of the hurricane test Version), Item 2B (in the hurricane test Version) and Item 2B (in the tsunami test Version) all loaded onto the same factor in Table 8. Responses for item 2 followed a similar pattern to responses for item 1. The results for Item 3 (Table 6) suggested that students, generally, did not appreciate the difference between science and pseudoscience (Lederman, 2007). This was seen as a concern that should be addressed by science educators. Educating the public on the difference between science and pseudo-science was seen to be of paramount importance, and merited more specific inclusion in future curriculum amendments or modifications. The outcomes for Item 4, related to recognizing there were creative, inferential and imaginative elements involved in the scientific process were similarly disappointing (Table 6), As Oyao et al., (2015) pointed out, creative, inferential and imaginative aspects of science were recognized as needed prerequisites for developing behavioral action during the event of a natural hazard or disaster. Thus, it seemed that students were lacking the recognition and conceptualization of the creative, imaginative and inferential aspects of NOS and merited inclusion in science teaching. The model put forth in Figure 1 and Figure 2 can be utilized to improve the recognition and conceptualization of NOS in science teaching. Results from Item 5 sought to determine whether students saw a relationship between theories and laws. Again, student responses were universally low (< 50% correct responses across all samples) (Table 6), which suggested that students did not adequately conceptualize the difference between a theory and a law. This finding was also in alignment with the literature (McComas, 1998; Lederman, 2007) and raised a further area of concern to be addressed by science educators.

Factor analysis was undertaken for all NOT-related Items. Outcomes showed that Items 6–9 did not load onto the same factor (as illustrated in Table 8). Although the Items related to a common theme based on the tenants from Project 2061 (AAAS, 1993), student NOT learning was inadequate. There seemed to be little indication, with respect to outcomes for NOT Items in [P3 – Tables 8 and 9] that technological concepts were being promoted in schools. A potential reason for technological concepts not being promoted in schools, was because curriculum standards related to technological concepts were missing in curriculum standards (MEXT, 2009; Estonian Government, 2011). Table 6, also illustrated that there was no clear indication of a learning progression from the basic to the advanced level, neither for any sample, nor for any natural hazard test type. Such findings were in alignment with the literature, which illustrated that NOT (Constantinou et al., 2010; Liou, 2015) was poorly understood by students. This implied that teachers were not teaching NOT in a sufficiently appropriate manner, and thus students were not adequately conceptualizing the consensus aspects of NOT. Overall, while comprehending NOS and NOT were viewed by science researchers as important for science education (NSTA, 2020), this study indicated that its clarity of transmission into curricula and teaching intentions was of concern. This was seen as being in alignment with findings from the literature (Lederman, 2007) and suggested this was still an area of concern. Unfortunately, NGSS (NGSS, 2013) and the Estonian National Curricula (Estonian Government, 2011) only mention NOS, while the Japanese curriculum (MEXT, 2009) did not include any reference to NOS/NOT (at the time of testing). Thus, a major implication of this could be the need to place greater emphasis on the need to include NOS and NOT in school science curricula, along the lines illustrated in Figure 2. This further supported the finding that NOS and NOT outcomes were not indicative of a progression in the learning from basic to advanced levels.

In responding to NOT test Items, students in the US West Coast and Japan, on average, gave the highest mean proportion of correct responses (Table 6). This suggested that NOT (Constantinou et al., 2010) conceptualizations were relatively weak in Estonia and the US East Coast. Furthermore, as the curriculum standards in Japan, which was accompanied by a guide towards teaching and learning, were devoid of mention with respect to NOT at the time of testing, this suggested that students from Japan might have acquired NOT knowledge outside of school e.g. students were acquiring competences related to NOT informally. Despite this, outcomes (Table 6) generally suggested that student learning of NOT was not seen as appropriate and pointed to the need for greater attention to promoting NOT conceptualization through earth science teaching.

For Item 6, results were relatively lower (see next paragraph on item 7) when compared with Items 7 to 9. Results for Item 6 were higher for the US East Coast and lower for Japan, suggesting that students from Japan did not recognize artificially induced earthquakes using technology at the time of testing (2016). Noting Item 6 related to utilizing technology to induce earthquakes, the outcome implied that students did not adequately understand that earthquakes could be artificially induced and further implied a lack of adequate NOT teaching in science classes. Mean results for Item 7 "Because humans can control nature by using technology, it was possible to build a home in any location", were relatively low when compared with responses to other NOT Items. This was perhaps because students did not adequately understand the question. In other words, the Item lacked a meaningful context, where 'in any location' was too vague ~~an~~ expression to utilize in the student test.

In general, the mean test outcomes for Items related to determining average disposition responses were higher across all samples. The significant correlations (Table 7) between dispositions and responsible behavioral action were particularly noteworthy and warranted further research on ways that science teaching exploited the connection between dispositions and behavioral action.

Item 10 related to the prioritization of safety between self and others with a view towards determining willingness to assist others during the event of a natural hazard. Results were high in all samples, but particularly high on the US East Coast. While Item 11 was related to the prioritization of personal safety alongside financial gain, Item 12 assessed student dispositions towards learning how to respond to a tsunami, with a view towards examining the relationships between dispositions associated with behavioral action (Sims & Baumann, 1983) and physical location. Mean scores for Items 11 and 12 were relatively high (Table 6), particularly in the student test sample from Japan. Item 13 asked students to reflect on whether learning about earthquakes was only important if you lived near a plate boundary, or fault line. Results were generally weak, except in Japan, where more than 3 times as many students in the sample tested (81.2%) positively responded than on the US West Coast (24.0%). Japan, and the US West Coast students indicated that they experienced more earthquakes than students on the US East Coast (16.8%) and students in Estonia (10.8%). Thus, students living in earthquake prone areas tended to hold more positive attitudes towards acquiring the competences necessary to respond to natural hazards in ways that reduced risks and saved lives. In other words, when behavioral actions were expressed by students associated with a positive belief, the students were more likely to undertake responsible behavioral action. And hence, based on the API (per country), it seemed to be important to reinforce the teaching approach advocated in the models (Figures 1 and 2) based on a connection between dispositions (OECD, 2019) and behavioral actions (such as a willingness to put forward meaningful responses to hurricanes, lightning strikes, earthquakes and tsunamis).

NOS, NOT and Depositions responses Compared against Perception of Danger with Respect to Natural Hazards

Table 15 indicated that there were few significant correlations between NOS (McComas, 1998; Lederman 2007; Fernandes, Rodrigues, & Ferreira, 2017), NOT (Constantinou et al., 2010) or disposition (OECD, 2019) related-items and a perception of danger with respect to natural hazards i.e. the responses given by students were seen as isolated with no conception and utilization of the learning progression as per Figure 2. Figure 2 was seen as a suitable model for indicating the explicit connection between NOS and NOT conceptualizations and perceptions of danger with respect to natural hazards.

Category 3 The Inter-relationship between Science and Technology

The student mean responses to category 3 (P3 – Table 10) suggested that students did not adequately comprehend the inter-relationship between science and technology. This item was included in the student test with a view towards determining whether a bi-directional relationship between science and technology was recognized by students, i.e., a relationship implying that technology improved science and science improved technology. The majority of students did not identify such a bi-directional relationship. The implication related to this concern was seen that the inter-relationship between NOS and NOT was not being sufficiently promoted in science teaching. The students' weak performance (across all countries/regions) indicated the need to pay more attention to the promotion of student familiarity, interaction and comprehension of both NOS and NOT, both implicitly and explicitly if appropriate. in curricula e.g. in NGSS (NGSS, 2013) science standards in Japan (MEXT, 2009) and in the Estonian National Curriculum (Estonian Government, 2011).

Category 4 Student Perceptions of the dangers posed by Natural Hazards

Based on the results in Table 10, student responses generally implied that natural hazards most experienced were viewed as the least dangerous, although students also indicated mixed responses, except in Japan (e.g. lightning was both the most and least feared at once by many students). While significant correlations between experience with, and perception of, earthquakes were found in the US West Coast sample, with respect to basic student test results (Table 10), this was not the case at the advanced level. A similar finding was obtained from student outcomes from Estonia, related to lightning at the basic level. However, findings from studies on the relationship between previous experience, preparedness, and danger perception in disaster situations were inconsistent (Bronfman et al., 2019). While student test responses indicated that tsunamis were the most dangerous natural hazard when compared with hurricanes, lightning and earthquakes (Figure 6), a study by Cvetković (2019) suggested a strong relationship between experience with natural hazards and fear. This implied that natural hazards feared the most were those experienced the least, with the reverse being true i.e. where natural hazards that were feared the least were experienced most often (as was the case for lightning strikes).

Nevertheless, significant correlations between student experience and perception of danger (as illustrated in Table 10) emerged, illustrating similar responses from students between Estonia/US East Coast (countries primarily experiencing meteorological dangers) and US West Coast/Japan (primarily experiencing tectonic dangers). These findings were in alignment with the suggestion by Bronfman et al., (2019) that there was a link between experience with natural hazards and perceived danger with respect to the same natural hazards.

Category 5 Student behavioral action during a natural hazard event

Overall, the student test in all countries-regions (Table 12) pointed to a lack of significant correlation between experience with natural hazards and behavioral action. The lack of a significant correlation between experience with natural hazards and behavioral action indicated either a lack of teaching/learning of behavioral action, or that experience without teaching and learning using the model put forth in Figure 1 did not meaningfully impact on behavioral action outcomes during the event of a natural hazard. Figure 2 illustrates a learning progression by which NOS and NOT were taught throughout the learning progression, supporting the learning of cross cutting skills (NRC, 2012) (such as problem solving, decision making, systems thinking, etc.) towards gaining the ability to put forward behavioral actions. It was thus postulated that if the model were to be adequately applied for teaching, the experience would more meaningfully impact on behavioral action with respect to natural hazards.

The findings in Table 11 implied that students, in general, seemed to find it difficult to respond to, and give, responsible behavioral actions. This applied to all the natural hazards and for students across all countries/regions. For example, results from students on the US West Coast showed that only a little over one third of the student sample responded responsibly in reaction to lightning strikes (41.6% – Table 11). This suggested a possible relationship between experience with lightning and behavioral action. However, results from a study by Phillips & Schmidlin (2013) suggested no connection between experience with lightning and lightning safety knowledge. This suggested that experience (or awareness in terms of API) did not necessarily translate into competences (preparedness in terms of API) with respect to natural hazards.

Students included in the student test sample from Estonia showed the highest percentage of responsible behavioral actions with respect to tsunamis (Table 11), which was surprising, because students from Estonia indicated, in general, that they were not exposed to the threats posed by tsunamis. This contrasted with percentage responses, for lightning and hurricanes, from the student sample in the US West Coast, who gave the highest proportion of responsible behavioral action responses in this respect, which suggested a possible emphasis to either teaching and learning of natural hazards in schools, or learning through the media (Esteban et al., 2018).

In general, student test responses, indicating that students putting forward meaningful behavioral action, were highest with respect to tsunami behavioral action, whilst responses were lowest with respect to earthquake behavioral action. The reason for this could be because the tsunami test Items more closely reflected feeling and were thus more associated with dispositions (OECD, 2019), while earthquake test Items were seen as more closely associated with gained knowledge and skills. The test outcomes indicated there were poor meaningful responses to the hurricane scenario, (around the 50% mark), although lower in the case of the Estonian sample (Table 11). One example by which the lack of meaningful behavioral action was illustrated by a high number of students (about 50%) who opted to use a bicycle (compared with walking, using a boat or car), but then who further stated they would take a bicycle to the mountain top, without giving consideration that at the top there would be no shelter! While this might be a responsible action in the event of a tsunami, it was not deemed suitable in the case of a hurricane.

Surprisingly, only around 60% students, over all regions, were able to identify areas on the fictitious island nation map (Appendix 3) that were considered safer in the event of a lightning strike. This suggested that while lightning safety knowledge was understood by the majority of students, there were still students who did not understand risks associated with lightning strikes. Nevertheless, the majority of students (who responded to the test instrument with respect to lightning) were aware of the dangers associated with lightning strikes, as most students were able to identify the most dangerous location (about 2/3rd of students tested gave a positive response). This further pointed to the familiarity of the risks associated with natural hazards that were media related (Esteban et al., 2018).

Although behavioral action in the case of a natural hazard was mentioned explicitly in the Japanese curriculum (MEXT, 2009), Japanese responsible behavioral action results were only higher with respect to responses to earthquakes, where the sample of Japanese students indicated they had most commonly experienced earthquakes (99.2%). Tsunami responses showed the highest percentage of responsible behavioral actions (Table 11), as well as the highest level of fear (Figure 6), yet the lowest level of experience (Figure 4). This suggested that other factors besides learning in school impacted on decision making e.g. media influence on behavioral action beyond actual experiences. This suggested that more attention to teaching associated with responsible behavioral actions in the case of natural hazards should be promoted as a key learning aspect, as put forward in the model in Figure 2.

The inadequate behavioral action outcomes (as indicated in Table 11) suggested teaching was not likely to be focusing on cross cutting skills, both crucial for NDR, as behavioral action encompasses cross cutting skills such as problem solving, decision making and creative thinking (United Nations, 1989) and raised a question as to whether the Awareness and Preparedness Index was actually at a sufficiently high level for any country.

The Interrelationship between NOS, NOT, Dispositions and putting forward Natural Hazard related, Responsible Behavioral Actions

Table 7 showed positive correlation coefficients between responses to disposition Items (Items 10–13 from category 2) were significant (Items 10, 12 and 13) indicating that science teacher had been more effective at fostering the development of values and attitudes (compared with promoting the specific conceptualizations of NOS and NOT), suggesting a connection between positive dispositions and behavioral action, particularly with respect to the tsunami test Version. Research by McIvor and Paton (2007) indicated that the following skills increased the likelihood of adopting protective measures for earthquakes:

(1) positive attitudes towards natural hazard mitigation;
(2) existing in a social context that advocates adopting protective behaviors;
(3) belief in the effectiveness of personal mitigation (outcome expectancy), and;
(4) good problem solving (action coping) skills.

Table 16 results indicated significant correlations between responses to Items where there was no meaningful learning and an emphasis was placed on teaching and learning competences with respect to NOS (McComas, 1998; Lederman 2007; Fernandes et al., 2017), NOT (Constantinou et al., 2010) and dispositions (OECD, 2019). The findings further indicated that test Items were seen as isolated Items (by students), meaning there was no coherent link (seen by students) between the 5 NOS-related Items (and between the 4 NOT-related Items). Student responses for Version B were stronger as illustrated by the generally higher means for individual Version B Items, relative to the corresponding Version A Item, even though the Version B Item provided a choice of answer. Furthermore, there was little overlap between responses to NOS-related Items (neither the Version A nor Version B Versions), for NOT-related Items (from category 2.2.2) and it was only in the disposition-related Items (seeking attitudes) that responses were similar. The responses were basically guessing (because there seemed to be no rhyme or reason as to patterns/sequences of responses) whether at the basic or advanced levels.

6.4 Teacher Questionnaires and Interviews

The teacher questionnaire was designed to determine whether teachers indicated they had taught natural hazards and related aspects to students between grades 6–12 in the USA. Results suggested that the majority of teachers participating in the questionnaire viewed NOS as gaining information and conceptualization and did not recognize the creative and innovative aspect of NOS (Table 17 – Items 3b & 4b). Nor did teachers recognize the distinction between a theory and a law (Table 17; Item 7). Fortunately, teachers seemed to recognize the empirically based aspect of NOS (Table 17; Item 3c). With respect to NOT, it seemed that teachers recognized the creative and innovative aspects of NOT more than they did for NOS (Table 17; Items 4b and 6b). AAAS (1993) pointed out that NOT, not only encompasses aspects of creativity and innovation, but also improvement and usefulness. However, teachers were less in agreement that technology needed to be seen as useful and an improvement on existing operations. This highlighted weaknesses among teacher competence with respect to aspects of NOT and thus pointed to a reason for the poor outcomes from students. The teacher's responses indicated relatively high recognition of the use of technology as a creative or imaginative element (Table 17 – Item 6b). Teachers felt it was necessary to teach technology related to science. Teacher questionnaire results were relatively lower for Items 6a and 6c (Table 17), compared with all other teacher questionnaire results, suggesting that technology was useful and improving, respectively. Teachers need to foster students' technological ideas in seeking scientific solutions to problems.

Results on the inter-relationship between NOS and NOT (Table 17 – Item 7) suggested that teachers generally did not recognize the bi-directional relationship between science and technology, in alignment with previous research that indicated the inter-relationship between NOS and NOT was generally mis-understood (Constantinou et al., 2010). While science endeavors were seen by scientists as dependent on technology (Bunge, 1966), technology operations were very much based on scientific conceptualizations (Brooks, 1994). As a result of the poorly conceived relationship between NOS and NOT, improvements with respect to teacher competences on the inter-relationship between NOS and NOT, were needed.

While Item 8 in the teacher questionnaire sought to determine teacher familiarity with NGSS, teacher responses to Items 9 and 10 (Table 17) indicated that, for those teachers familiar with NGSS, and viewed NGSS as playing a dominant role in guiding science teaching, especially associated with natural hazards.

While NGSS highlighted 'natural hazards' (NSTA, 2020), unfortunately it did not explicitly include NDR. It was thus, perhaps, not surprising that 25% of teachers in response to Item 11 were dubious whether NGSS adequately promoted student learning related to natural hazards and associated NDR. Attitudinal and dispositional learning outcomes were, at best, seen as tokenistic. Nevertheless, the teachers viewed responsible behavioral action as an important component of earth science teaching. NGSS should therefore include more reference to NDR due to an increased frequency and magnitude of natural disasters to reduce risks and save lives.

Items 12 and 13 probed teacher dispositions towards teaching NDR. Outcomes from the teacher questionnaire were positive (>90%) and suggested that teachers were in favor of promoting NDR (Pisano, 1998) and RBA in teaching and learning NH.

Item 14 probed teacher dispositions on whether or not to evacuate during a hurricane. Results suggested that the surveyed teachers unanimously agreed that it was necessary to evacuate if given an evacuation warning.

Item 15 probed teacher views on the model in Figure 2. Figure 2 was supported by teachers as the framework in Figure 2 (Table 17, Item 15) was considered as an effective model for developing teacher/learner materials. Teaching and learning with respect to the model (Figure 2) clearly required students to go beyond textbook knowledge and, for students to put forward responsible behavioral actions. Teacher questionnaire Items 15–17 suggested that teachers recognized a natural learning progression. In other words, teachers recognized the need to teach students in a context to which they could relate (Obasi, 1994).

Items 18–19 probed teacher views on teaching behavioral actions (Sims & Baumann, 1983) (Table 18, Item 18) and in particular, promoting the use of the map put forth in Appendix 3 to teach NDR (Table 18, Item 19). Results suggested that teachers support teaching RBA, through the use of such maps.

Teacher Interviews

Teacher interviews were devised with a view towards validating outcomes from the teacher questionnaire.

The interviews were conducted separately by asking 5 questions, as indicated in Table 18.

Category 1, re- the meaning of NOS, all interviewed teachers agreed that it was expected that all teachers that participated in the questionnaire responded positively to creativity and observations being seen as important aspects in the teaching of earth science. The interviewed teachers also unanimously indicated that in agreement with Lederman & Abd-El-Khalick, (1998) exhibiting imagination and creativity were important scientific endeavors. Thus, the interviewed teachers confirmed that all components of Items 3 and 4 related to NOS in the teacher questionnaire were desired goals in science teaching.

Category 2 relating to NOT, the interviewed teachers felt it was important to promote NOT conceptualizations. This contrasted where teachers were less certain that technology needed to be seen as useful and to be seen as an improvement on existing operations and hence rejected these aspects as not important to teach. This point seemed to be little discussed in the literature. However, when the interviewed teachers were asked to clarify their views on the role of technology and its bi-directional relationship with NOS. All interviewed teachers indicated their strong agreement towards the essential role of technology in science teaching and the use of technology as a creative or imaginative element (Lederman, 2007), based on scientific foundations.

Category 3 of the teacher interview solicited teacher familiarity with respect to NGSS (NGSS, 2013). The interviewed teachers, as well as the teachers completing the questionnaire, recognized NGSS inclusion of relevant NDR content in NGSS. It seemed, based on interview results, that teachers were even supportive of further inclusion for standards related to NDR.

Category 4 of the teacher interview was purposely asked to relate to natural hazards with a view towards determining experienced teacher views with respect to teaching and learning of NDR. NDR (Pisano, 1998) was seen as a familiar term for these teachers (from inclusion in NGSS), and hence they were positive towards the teaching of NDR (Table 18) and noting this, the interviewed teachers all concurred with this almost unanimous positive teacher responses to all the related questionnaire Items regarding NDR. This suggested a need to reflect further on the degree to which NH and the related NDR were sufficiently emphasized in today's earth science teaching, as there seemed to be a gap between interview responses for category 4 and student test outcomes.

Category 5 of the teacher interview was purposely asked to determine teacher competences (Chaudhry et al., 2020) with respect promoting responsible behavioral action, as proposed in the model (Figure 2). The interviewed teachers indicated that behavioral action scenario was a very suitable teaching approach for students, particularly using put forward in Appendix 3. All interviewed teachers saw this approach as meaningful and suitable to enable measurement of students' behavioral action during the event of a natural hazard. The 6 teachers individually interviewed went further and even suggested why not involve students in putting forward their own unique, yet responsible behavioral actions. Additionally, the teachers interviewed unanimously agreed that, although authentic scenarios could be more suitable, developing an artificial natural hazard scenario (as shown in Appendix 3) seemed a more practical way to teach responsible behavioral actions and implied a need for teaching/learning materials that corresponded with the models (Figures 1 and 2). Not surprisingly, all interviewed teachers supported the inclusion of specific NDR in future curricula modifications.

6.5 Limitations

The following limitations are put forward.

- The number of countries involved was limited to three (Estonia, United States and Japan) for the student sample, and was thus a small sample when compared with the API, allowing fewer interpretations between the student test and the API. This is a small proportion of the world's countries in its interlinking with the API index, and thus there was less validity associated with a lower student test sample size (limited to three countries). The student test sample in this study was chosen through a convenience sample and was thus a non-parametric sample. If the sample had been parametric, the results from the student test may have turned out different and thus the non-parametric convenience sample in this research lowered the validity in this research. In future research studies, student tests should be consistent throughout one country with a parametric sample (representative sample) where the results are directly comparable between individual countries in subsequent research.

- In recognising the need to relate to a range of natural hazards, the student test design was separated into four test versions (Hurricane, Lightning, Earthquake and Tsunami) where items included in one test version weren't necessarily included in another, as there were too many items to include in each version given the high proportion of items from other sections limiting comparisons between test versions. For the behavioral action section of the test, to consolidate from 4 to 2 test versions, there should be two natural hazards (one meteorological and one tectonic natural hazard) because having two versions (instead of four) would enable more direct comparisons between tests, i.e. poor test design. Having two test versions would increase the validity of future research.
- To determine the suitability of the model for undertaking data collection, this research sought to test all aspects of the NDR Learning Progression Model. This led to limited testing in any one test category (such as NOS, NOT, Dispositions or Behavioral Action) against the models put forth in figures 1 and 2. Results were spread far and few between and hence were less interpretable (data is poor and limited in both validity and reliability in its interpretation) and resulted in the decreased validity of the test results. Thus, two versions (one meteorological and one tectonic NH Version) of the test with an increased number of items for NOS and NOT, but otherwise identical tests are recommended in future studies;
- The sample with respect to the teacher questionnaires (N=35) and interviews (N=6) were limited. Future samples should also be inclusive of a higher frequency of teachers to increase the validity of the study. Interviews were necessary to complement the teacher questionnaire because the teacher questionnaire respondents did not often complete the explanation items. The frequency for the teacher questionnaire sample should be at least 50 whilst the teacher interview sample should be at least 30. An increased sample for teacher questionnaires and interviews should lead to increased validity.
- With respect to the Awareness and Preparedness Index (API), data (World Risk Index and PISA) were not normalized. Normalization of data was not considered necessary because data had not separated into multiple tables. Future research should encompass data normalization of data.

6.6 Recommendations

Based in on the outcomes of this PhD thesis and considering experiences gained during the PhD studies, following recommendations can be formed.

- The increasing intensity of many NH and accompanying dangers to life are being attributed to the rising air temperatures. The low student NDR responses in this research points to the need for more attention to be paid to NH and NDR in school teaching, especially coverage beyond the factual/knowledge level.
- In some countries around the world, geography is seen as a science subject and NH, if taught, is within an Earth science section. With a need for greater attention to NH and NDR at both basic and advanced level teaching, it is recommended that Earth science be explicitly taught with sufficient emphasis (within a STEM portrayal to ensure links to NOS and NOT) and labelled as such in all countries.
- Based on the poor response to test items related to NOS and NOT, suggesting students are gaining a poor image of both science and technology, it is recommended that science teaching, and earth science teaching in particular, pay attention to the conceptualization of science beyond biology, chemistry and physics and technology as applied science, by incorporating conceptualizations encompassing the image, limitations and parameters under which both science and technology function.
- Based on the derived model, it is recommended that the teaching of Earth science and NDR in particular, pay attention to the teaching approach e.g. initial familiarization of the teaching situation leading to a de-contextual conceptualization of the science and involving further re-contextual science learning.
- Further based on the model, it is recommended that the re-contextualization of the initial NH situation guide students toward putting forward responsible behavior actions, thus, promoting student-centered teaching, involving students in the development of self-actualization.
- To facilitate student NH-NDR learning in a meaningful context, it is recommended to utilize real situations, or failing that to simulate meaningful artificial contexts such as that indicated in Appendix 3.
- Noting the poor responses to the teacher questionnaire on items associated with NOS and NOT, it is recommended that greater attention is paid to ensure science teachers, and earth science teachers in particular, are guided to conceptualize both NOS and NOT. And thus there is a need for more teaching professional development with respect to improving teaching competences towards NOS and NOT conceptualization.
- It seems, from the teacher questionnaire responses, that teachers are not familiar with the various attributes of the model. This points to the curriculum needing to be made more explicit, plus a greater need for teacher professional development to help refocus the teaching towards society needs.

7. CONCLUSIONS

This thesis devised a country Index (API) shown to be meaningful in interrelating an awareness of, and meaningful preparation for, natural hazard disaster reduction. The preparedness was based on scientific literacy-related, students' PISA2018 science scores. This was interrelated with a population awareness of the risk factors, specifically the WRI subcomponents, indicating the degree to which a country's lack of adaptive capacities (LoA) and with this the lack of coping capacities (LoC) related to a readiness to handle natural hazards and especially NDR. As a general indicator, lacking in high measures of reliability, it was seen as giving a relative suitability indication of natural hazard awareness and preparedness (based on science education standards) in the countries involved in this research.

In general, the model, considered from a theoretical perspective (Figure 1) and a teaching orientation (Figure 2), promotes a learning progression towards NH, NDR and RBA. The model serves as a meaningful guide toward supporting the teaching and learning for promoting responsible behavioral action. The model was further shown to support a philosophical appreciation of what was meant by science, and draws attention to the need for students to gain an understanding of NOS and NOT, irrespective of the learning level. The model further supported the need for more positive dispositions towards learning as an important aspect in the teaching, and also, a willingness to develop the attributes identified in a progressive 4 level approach towards students' self-actualization for undertaking responsible behavioral actions.

Students were able to put forward familiar actions with respect to natural hazards, as opposed to actions that were unfamiliar and which required transference of learning but being able to indicate responsible behavioral actions seemed to be generally lacking. Positive dispositions (attitudes and values/beliefs), e.g. a willingness to evacuate under the threat of an impending natural hazard/ disaster, suggested an increased student ability to undertake responsible behavioral actions in the event of a natural hazard. There was a lack of a demonstrable link between NOS and NOT and responsible behavioral actions. But, on the other hand, it seemed that the more the student data indicate a gain in positive dispositions, the more support there is for the undertaking of responsible behavioral actions.

Teachers felt it was of value for students to be able to learn how to act responsibly during an imaginary natural disaster in ways that reduced risks and saved lives. Teacher indicated that the learning progression put forward in Figure 1 and Figure 2 was recognized as potentially an effective frame for students to be able to promote their learning, associated with transference of learning so as to put forward responsible behavioral actions. Nevertheless, teachers needed more guidance to promote NH and NDR than simply the curriculum and its inclusion of disciplinary topic areas plus interdisciplinary cross-cutting actions.

APPENDICES

Appendix 1. PISA2018 (OECD, 2019) and World Risk (UNU, 2016) Data for each of the 30 Selected Countries

#	Country	PISA score	World Risk Index	Expo-sure	Vulner-ability	Suscepti-bility	Lack of coping capacities	Lack of adapting capacities
1	Belgium	499	3.4	11.7	29.2	15.6	42.4	29.7
2	Brazil	404	4.3	9.5	45.1	25.5	66.6	43.2
3	Brunei Darussalam	431	16.2	41.1	39.5	18.0	63.1	37.4
4	Canada	518	3.1	10.3	30.6	15.2	46.5	30.2
5	Chile	444	11.3	31.0	36.5	20.2	58.5	30.8
6	Costa Rica	416	17.3	42.6	40.7	23.0	64.6	34.5
7	Cyprus	439	2.8	7.4	37.1	14.9	58.1	38.5
8	Czech Republic	497	3.5	10.8	32.0	15.1	50.9	30.1
9	Estonia	530	2.4	7.2	37.2	18.7	51.2	30.9
10	Finland	522	2.2	8.2	27.4	15.6	39.4	27.2
11	France	493	2.7	9.3	29.1	16.1	43.3	27.8
12	Georgia	383	6.8	14.7	46.3	28.2	64.8	45.9
13	Indonesia	396	10.5	19.4	54.5	32.1	81.0	50.4
14	Ireland	496	4.5	14.7	30.6	16.1	46.6	29.3
15	Japan	529	13.4	45.9	29.1	17.6	38.3	31.6
16	Kazakhstan	397	3.7	9.1	41.1	18.0	63.6	41.7
17	Lithuania	482	3.0	8.9	33.9	18.6	49.4	33.8
18	Mexico	419	6.3	13.8	45.3	24.0	72.2	39.7
19	North Macedonia	413	6.1	14.4	42.7	20.9	64.4	42.8
20	Panama	365	7.4	16.5	45.0	27.9	67.9	39.3
21	Peru	404	6.9	14.4	48.0	29.6	73.3	41.2
22	Philippines	357	28.3	52.5	53.9	33.6	80.0	48.2
23	Portugal	492	3.6	10.9	33.0	17.9	48.4	32.7
24	Romania	426	6.6	15.2	41.5	22.1	61.4	41.1
25	Serbia	440	6.9	18.1	38.3	18.5	66.2	30.3
26	Singapore	551	2.3	7.8	27.8	14.1	49.2	22.7
27	Slovak Republic	464	3.6	10.2	34.9	14.5	55.7	34.6
28	Slovenia	507	3.6	11.6	31.4	16.0	51.2	27.1
29	Spain	483	3.2	10.2	31.3	16.1	52.0	25.7
30	United States	502	3.9	12.3	31.7	16.5	48.6	30.0

Appendix 2a. Estonian student responses at the basic level to each Item tested in each of the 4 Versions

Estonia – Hurricane – Basic Level																									
Item	**1A**	**1B**	**2A**	**2B**	**3A**	**3B**	**4A**	**4B**	**5A**	**5B**	**6A**	**6B**	**7A**	**7B**	**8A**	**8B**	**9A**	**10A**	**10B**	**11A**	**11B**	**12A**	**12B**	**13A**	**13B**
	NOS Items											**NOT Items**								**Disposition Items**					
N		77		77	77			77			77		77					77				77		77	
Mean		0.12		0.23	0.51			0.12			0.78		0.25					0.55				0.34		0.26	
SD		0.31		0.42	0.5			0.32			0.41		0.43					0.5				0.47		0.44	

*9B was not included in any test format

Estonia – Lightning – Basic Level																									
Item	**1A**	**1B**	**2A**	**2B**	**3A**	**3B**	**4A**	**4B**	**5A**	**5B**	**6A**	**6B**	**7A**	**7B**	**8A**	**8B**	**9A**	**10A**	**10B**	**11A**	**11B**	**12A**	**12B**	**13A**	**13B**
	NOS Items											**NOT Items**						**Disposition Items**							
N	119					119	119		119			119		119	119					119			119		119
Mean	0.29					0.38	0.21		0.78			0.19		0.69	0.13					0.11			0.97		0.93
SD	0.46					0.49	0.41		0.41			0.4		0.46	0.34					0.31			0.18		0.25

Estonia – Earthquake –Basic Level																									
Item	**1A**	**1B**	**2A**	**2B**	**3A**	**3B**	**4A**	**4B**	**5A**	**5B**	**6A**	**6B**	**7A**	**7B**	**8A**	**8B**	**9A**	**10A**	**10B**	**11A**	**11B**	**12A**	**12B**	**13A**	**13B**
	NOS Items											**NOT Items**						**Disposition Items**							
N	111		111							111		111				111	111		111	111					
Mean	0.16		0.01							0.05		0.69				0.65	0.26		0.82	0.75					
SD	0.37		0.09							0.23		0.46				0.48	0.82		0.39	0.44					

Estonia – Tsunami – Basis Level																									
Item	**1A**	**1B**	**2A**	**2B**	**3A**	**3B**	**4A**	**4B**	**5A**	**5B**	**6A**	**6B**	**7A**	**7B**	**8A**	**8B**	**9A**	**10A**	**10B**	**11A**	**11B**	**12A**	**12B**	**13A**	**13B**
	NOS Items											**NOT Items**						**Disposition Items**							
N			68		68		68		68								68		68		68		68		
Mean			0.84		0.74		0.53		0.6								0.28		0.24		0.15		0.81		
SD			0.37		0.44		0.5		0.49								0.45		0.52		0.36		0.4		

Appendix 2b. Estonian student responses at the advanced level to each Item tested in each of the 4 Versions

Estonia – Hurricane – Advanced Level

Item	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	7A	7B	8A	8B	9A	9B	10A	10B	11A	11B	12A	12B	13A	13B
	NOS Items											NOT Items							Disposition Items							
N		101		101	101			101			101		101			101			101				101		101	
Mean		0.05		0.34	0.03			0.21			0.03		0.29			0.52			0.03				0.06		0.03	
SD		0.22		0.47	0.17			0.41			0.17		0.45			0.5			0.17				0.24		0.17	

Estonia – Lightning – Advanced Level

Item	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	7A	7B	8A	8B	9A	9B	10A	10B	11A	11B	12A	12B	13A	13B
	NOS Items											NOT Items							Disposition Items							
N	48					48	48		48			48		48	48						48			48		48
Mean	0.21					0.56	0.42		0.73			0.35		0.6	0.04						0.46			0.96		0.94
SD	0.41					0.5	0.49		0.44			0.48		0.49	0.2						0.5			0.2		0.31

Estonia – Earthquake – Advanced Level

Item	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	7A	7B	8A	8B	9A	9B	10A	10B	11A	11B	12A	12B	13A	13B
	NOS Items											NOT Items							Disposition Items							
N	56		56							56		56				56	56			56	56					
Mean	0.16		0.84							0.74		0.41				0.52	0.38			0.8	0.84					
SD	0.37		0.37							0.4		0.5				0.5	0.49			0.4	0.37					

Estonia – Tsunami – Advanced Level

Item	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	7A	7B	8A	8B	9A	9B	10A	10B	11A	11B	12A	12B	13A	13B
	NOS Items											NOT Items							Disposition Items							
N			60		60		60		60								60			60		60		60		
Mean			0.02		0.03		0.15		0.8								0			0.22		0.22		0.98		
SD			0.13		0.18		0.36		0.4								0			0.52		0.42		0.13		

Appendix 2c. US East Coast student responses at the basic level to each Item tested in each of the 4 Versions

US East Coast – Lightning – Basic Level																										
Item	**1A**	**1B**	**2A**	**2B**	**3A**	**3B**	**4A**	**4B**	**5A**	**5B**	**6A**	**6B**	**7A**	**7B**	**8A**	**8B**	**9A**	**9B**	**10A**	**10B**	**11A**	**11B**	**12A**	**12B**	**13A**	**13B**
	NOS Items											**NOT Items**							**Disposition Items**							
N	121					121	121		121			121		121	121						121			121		121
Mean	0.41					0.62	0.25		0.69			0.37		0.64	0.15						0.11			0.81		0.86
SD	0.49					0.49	0.43		0.46			0.49		0.48	0.36						0.31			0.39		0.35

US East Coast – Earthquake – Basic Level																										
Item	**1A**	**1B**	**2A**	**2B**	**3A**	**3B**	**4A**	**4B**	**5A**	**5B**	**6A**	**6B**	**7A**	**7B**	**8A**	**8B**	**9A**	**9B**	**10A**	**10B**	**11A**	**11B**	**12A**	**12B**	**13A**	**13B**
	NOS Items											**NOT Items**							**Disposition Items**							
N	71		71							71		71				71	71			71	71					
Mean	0.35		0.07							0.1		0.42				0.56	0.48			0.48	0.86					
SD	0.48		0.25							0.3		0.5				0.5	0.5			0.5	0.35					

Appendix 2d. US East Coast student responses at the advanced level to each Item tested in each of the 2 Versions

US East Coast – Hurricane – Advanced Level																										
Item	**1A**	**1B**	**2A**	**2B**	**3A**	**3B**	**4A**	**4B**	**5A**	**5B**	**6A**	**6B**	**7A**	**7B**	**8A**	**8B**	**9A**	**9B**	**10A**	**10B**	**11A**	**11B**	**12A**	**12B**	**13A**	**13B**
	NOS Items											**NOT Items**									**Disposition Items**					
N		105		105	105			105			105		105			105			105				105		105	
Mean		0.11		0.18	0.09			0.2			0.03		0.27			0.24			0.09				0.3		0.15	
SD		0.32		0.39	0.28			0.4			0.17		0.44			0.29			0.28				0.46		0.36	

US East Coast – Tsunami – Advanced Level																										
Item	**1A**	**1B**	**2A**	**2B**	**3A**	**3B**	**4A**	**4B**	**5A**	**5B**	**6A**	**6B**	**7A**	**7B**	**8A**	**8B**	**9A**	**9B**	**10A**	**10B**	**11A**	**11B**	**12A**	**12B**	**13A**	**13B**
	NOS Items											**NOT Items**									**Disposition Items**					
N			103		103		103		103								103			103		103		103		
Mean			0.04		0.06		0.07		0.89								0.02			0.14		0.43		0.97		
SD			0.19		0.24		0.25		0.31								0.14			0.34		0.5		0.17		

Appendix 2e. US West Coast student responses at the basic level to each Item tested in each of the 3 Versions

US West Coast – Hurricane – Basic Level

Item	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b	7a	7b	8a	8b	9a	9b	10a	10b	11a	11b	12a	12b	13a	13b
	NOS Items											NOT Items							Disposition Items							
N		65		65	65			65			65		65			65			65				65		65	
Mean		0.06		0.26	0.69			0.25			0.58		0.49			0.39			0.43				0.25		0.42	
SD		0.24		0.44	0.47			0.43			0.5		0.5			0.47			0.5				0.43		0.5	

US West Coast – Lightning – Basic Level

Item	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b	7a	7b	8a	8b	9a	9b	10a	10b	11a	11b	12a	12b	13a	13b
	NOS Items											NOT Items							Disposition Items							
N	40					40	40		40			40		40	40						40			40		40
Mean	0.1					0.35	0.2		0.1			0.28		0.58	0.45						0.55			0.68		0.8
SD	0.3					0.48	0.41		0.3			0.45		0.5	0.5						0.5			0.47		0.69

US West Coast – Earthquake – Basic Level

Item	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b	7a	7b	8a	8b	9a	9b	10a	10b	11a	11b	12a	12b	13a	13b
	NOS Items											NOT Items							Disposition Items							
N	27		27							27		27				27	27			27	27					
Mean	0.04		0.41							0.15		0.44				0.26	0.26			0.7	0.11					
SD	0.19		0.5							0.36		0.51				0.45	0.45			0.47	0.32					

Appendix 2f. US West Coast student responses at the advanced level to each Item tested in each of the 3 Versions

US West Coast – Lightning – Advanced Level																										
Item	**1a**	**1b**	**2a**	**2b**	**3a**	**3b**	**4a**	**4b**	**5a**	**5b**	**6a**	**6b**	**7a**	**7b**	**8a**	**8b**	**9a**	**9b**	**10a**	**10b**	**11a**	**11b**	**12a**	**12b**	**13a**	**13b**
	NOS Items											**NOT Items**							**Disposition Items**							
N	87					87	87		87			87		87	87						87			87		87
Mean	0.24					0.53	0.3		0.08			0.46		0.47	0.69						0.38			0.84		0.86
SD	0.43					0.5	0.46		0.27			0.5		0.5	0.47						0.49			0.37		0.51

US West Coast – Earthquake – Advanced Level																										
Item	**1a**	**1b**	**2a**	**2b**	**3a**	**3b**	**4a**	**4b**	**5a**	**5b**	**6a**	**6b**	**7a**	**7b**	**8a**	**8b**	**9a**	**9b**	**10a**	**10b**	**11a**	**11b**	**12a**	**12b**	**13a**	**13b**
	NOS Items											**NOT Items**							**Disposition Items**							
N	71		71							71		71				71	71			71	71					
Mean	0.31		0.85							0.08		0.58				0.45	0.34			0.83	0.04					
SD	0.47		0.36							0.28		0.5				0.5	0.48			0.38	0.2					

US West Coast – Tsunami – Advanced Level																										
Item	**1a**	**1b**	**2a**	**2b**	**3a**	**3b**	**4a**	**4b**	**5a**	**5b**	**6a**	**6b**	**7a**	**7b**	**8a**	**8b**	**9a**	**9b**	**10a**	**10b**	**11a**	**11b**	**12a**	**12b**	**13a**	**13b**
	NOS Items											**NOT Items**							**Disposition Items**							
N			86		86		86		86											86		86		86		
Mean			0.85		0.85		0.77		0.03								0.56			0.34		0.33		0.88		
SD			0.36		0.36		0.42		0.18								0.5			0.48		0.47		0.32		

Appendix 2g. Japanese student responses at the basic level to each Item tested in each of the 3 Versions

Item	**1a**	**1b**	**2a**		**2b**	**3a**	**3b**	**4a**	**4b**	**5a**	**5b**	**6a**	**6b**	**7a**	**7b**	**8a**	**8b**	**9a**	**9b**	**10a**	**10b**	**11a**	**11b**	**12a**	**12b**	**13a**	**13b**
	NOS Items											**NOT Items**								**Disposition Items**							
N	47		47							47						47				47							
Mean	0		0.09							0.02						0.68				0.36							
SD	0		0.6							0.15						0.47				0.49							

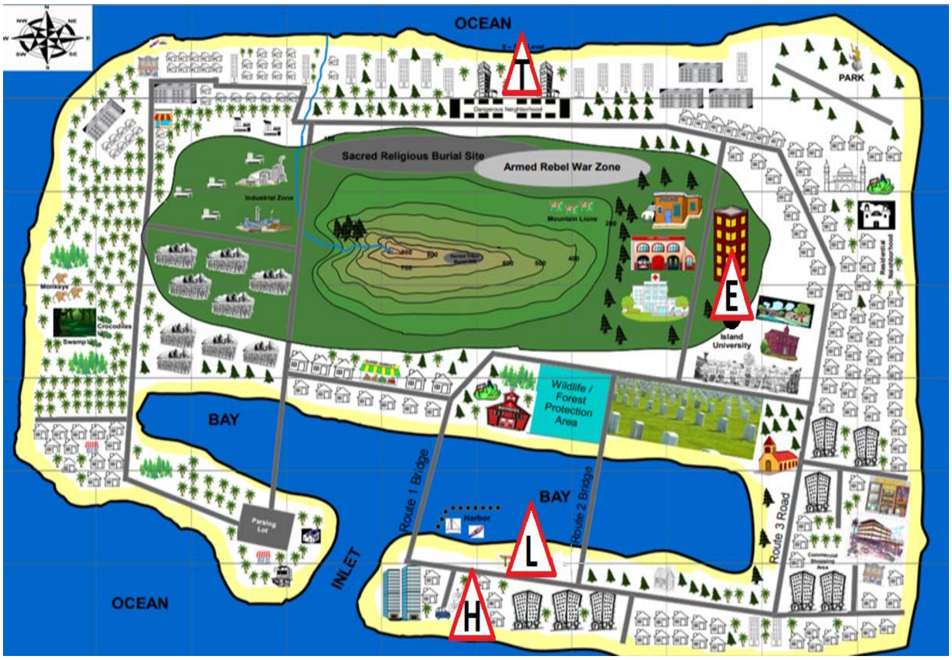
Item	**1a**	**1b**	**2a**	**2b**	**3a**			**3b**	**4a**	**4b**	**5a**	**5b**	**6a**	**6b**	**7a**	**7b**	**8a**	**8b**	**9a**	**9b**	**10a**	**10b**	**11a**	**11 b**	**12a**	**12 b**	**13a**	**13b**
	NOS Items												**NOT Items**								**Disposition Items**							
N	27		27								27				27										27		27	
Mean	0		0								0				0.67										0.63		0.19	
SD	0		0								0				0.48										0.49		0.4	

Item	**1a**	**1b**	**2a**	**2b**	**3a**	**3b**	**4a**	**4b**	**5a**	**5b**	**6a**	**6b**	**7a**	**7b**	**8a**	**8b**	**9a**	**9b**	**10a**	**10b**	**11a**	**11b**	**12a**	**12b**	**13a**	**13b**
	NOS Items											**NOT Items**							**Disposition Items**							
N							76	76									76	76					76	76	76	76
Mean							0.72	0.05									0.14	0.07					0.24	0.13	0.32	0.58
SD							0.45	0.22									0.35	0.25					0.43	0.34	0.47	0.5

Appendix 2h. Japanese student responses at the advanced level to each Item tested in each of the 2 Versions

Item	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b	7a	7b	8a	8b	9a	9b	10a	10b	11a	11b	12a	12b	13a	13b
	NOS Items											NOT Items							Disposition Items							
N	139		139		139																139				139	
Mean	0		0.76		0.75																0.81				0.47	
SD	0		0.43		0.44																0.4				0.5	

Item	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b	7a	7b	8a	8b	9a	9b	10a	10b	11a	11b	12a	12b	13a	13b
	NOS Items											NOT Items							Disposition Items							
N	96						96				96		96		96		96		96		96					
Mean	0						0.64				0.92		0.56		0.84		0.09		0.61		0.78					
SD	0						0.48				0.27		0.5		0.37		0.28		0.49		0.41					



Appendix 3. An Outset Map for Hurricane, Lightning, Earthquake and Tsunami Behavioral Action Scenarios in the Student Test

7. REFERENCES

AghaKouchak, A., Huning, L., Chiang, F., Sadegh, M., Vahedifard, F., Mazdiyasni, O., & Mallakpour, I. (2018). How do natural hazards cascade to cause disaster? *Nature, 561,* 458–460.

Allen, K., & Friedman, B. (2010). Affective learning: A taxonomy for teaching social work values. *Journal of Social Work Values and Ethics,7*(2), 1–12.

Alsharif, K. (2014). How do Teachers Interpret the Term 'Constructivism' as a Teaching Approach in the Riyadh Primary Schools Context? *Procedia – Social and Behavioral Sciences*. 141. https://doi.org/10.1016/j.sbspro.2014.05.170.

American Association for the Advancement of Science (AAAS). (1993). Project 2061: Benchmarks for Science Literacy. New York: Oxford University Press. http://www.project2061.org/publications/bsl/online/index.php

Anderman, E., Sinatra, G. & Gray, D. (2012). The Challenges of Teaching and Learning about Science in the Twenty-First Century: Exploring the Abilities and Constraints of Adolescent Learners. *Studies in Science Education, 48*(1), 89–117. Retrieved October 31, 2020 from https://www.learntechlib.org/p/75786/.

Astill, S. (2018). The importance of supervisory and organisational awareness of the risks for an early career natural hazard researcher with personal past-disaster experience. *Emotion, space and society,28*, 46–52.

Ausubel, D. (1960). The use of advance organizers in the learning and retention of meaningful verbal material. *Journal of Educational Psychology, 51*, 267–272. http://dx.doi.org/10.1037/h0046669

Bachmann, S. (2018). Epidemiology of suicide and the psychiatric perspective. *International journal of environmental research and public health, 15*(7), 1425.

Bada, & Olusegun, S. (2015). Constructivism Learning Theory: A Paradigm for Teaching and Learning.

Bandura, A. (1971). Social Learning Theory. General Learning Press, New York.

Beaton, D., Tang, K., Gignac, M., Lacaille, D., Badley, E., Anis, A., & Bombardier, C. (2010). Reliability, validity, and responsiveness of five at-work productivity measures in patients with rheumatoid arthritis or osteoarthritis. *Arthritis Care & Research: Official Journal of the American College of Rheumatology, 62*(1), 28–37.

Bentley, T. (2012). Learning beyond the classroom: Education for a changing world. Routledge.

Bereiter, C., & Scardamalia, M. (1989). Intentional learning as a goal of instruction. Knowing, learning, and instruction: Essays in honor of Robert Glaser, 361–392. Lawrence Erlbaum Associates, Inc.

Bernard, E., Titov, V. (2015). Evolution of tsunami warning systems and products. Philosophical transactions. *Series A, Mathematical, physical, and engineering sciences, 373*(2053), 20140371. https://doi.org/10.1098/rsta.2014.0371

Bhattacharjee, J. (2015). Constructivist approach to learning–an effective approach of teaching learning. *International Research Journal of Interdisciplinary & Multidisciplinary Studies*, *1*(4), 23–28.

Birgili, B. (2015). Creative and critical thinking skills in problem-based learning environments. *Journal of Gifted Education and Creativity, 2*(2), 71–80.

Birkmann, J. (2011). Regulation and Coupling of Society and Nature in the Context of Natural Hazards, Different theoretical approaches and conceptual frameworks and their applicability to analyse socialecological crises phenomena. In: Brauch HG, Oswald-Spring U, Kameri-Mbote P, Meajasz C, Grin J, Chourou B, Dunay P, Birkmann J (eds). Coping with global environmental change, disasters and security threats, challenges, vulnerabilities and risks. Springer, Berlin, pp. 1103–1127.

Birkmann, J., Garschagen, M., Mucke, P., Schauder, A., Seibert, T., Welle, T., Rhyner, J., Kohler, S., Loster, T., Reinhard, D., Matuschke, I. (2014). World Risk Report 2014. Bündnis Entwicklung Hilft and UNU-EHS.

Birkmann, J., and von Teichman, K. (2010). Integrating disaster risk reduction and climate change adaptation: key challenges – scales, knowledge, and norms. *Sustainability Science,5*(2),171–184.

Blackwelder, B. (1964). Kit Carson: A Portrait in Courage. University of Oklahoma Press, 158–160.

Blazar, D., Kraft M. (2017). Teacher and Teaching Effects on Students' Attitudes and Behaviors. *Educational Evaluation and Policy Analysis, 39*(1): 146–170. https://doi.org/10.3102/0162373716670260

Bloom, B. (1956). Taxonomy of educational objectives: The classification of educational goals. New York: Longmans, Green.

Bokwa, A. (2013). Natural Hazard. In Encyclopedia of Natural Hazards; Bobrowsky, P.T., Ed.; Encyclopedia of EarthSciences Series; Springer: Dordrecht, The Netherlands.

Bolte, C., Streller, S., Holbrook, J., Rannikmae, M., Naaman, R. M., Hofstein, A., & Rauch, F. (2012). PROFILES: Professional Reflection-Oriented Focus on Inquiry-based Learning and Education through Science. Nature of Science, History, Philosophy, Sociology of Science, 16.

Bronfman, N., Cisternas, P., Repetto, P., & Castañeda, J. (2019). Natural disaster preparedness in a multi-hazard environment: Characterizing the sociodemographic profile of those better (worse) prepared. *PLoS One, 14*(4). doi:10.1371/ journal.pone.0214249

Brooks, H. (1994). The relationship between science and technology. *Research policy, 23*(5), 477–486.

Brown, J. (2017). A metasynthesis of the complementarity of culturally responsive and inquiry-based science education in K-12 settings: Implications for advancing equitable science teaching and learning. *Journal of Research in Science Teaching, 54*(9), 1143–1173.

Brown, P., Daigneault, A., Tjernström, E., & Zou, W. (2018). Natural Disasters, Social Protection, and Risk Perceptions. *World development, 104,* 310–325. https://doi.org/10.1016/j.worlddev.2017.12.002

Bruner, J. (1960). *The Process of education.* Cambridge, Mass.: Harvard University Press.

Bunge, M. (1966). Technology as applied science. In *Contributions to a Philosophy of Technology* (pp. 19–39). Springer, Dordrecht.

Burby, R., Deyle, R., Godschalk, D., Olshansky, R. (2000). Creating Hazard Resilient Communities through Land-Use Planning. *Natural Hazards Review, 1*. https://doi.org/10.1061/(ASCE)1527-6988(2000)1:2(99).

Carroll, D. (2012). Examining the development OF dispositions for Ambitious Teaching: One Teacher CANDIDATE'S JOURNEY. *The New Educator, 8*(1), 38–64. doi:10.1080/1547688x.2011.619950

Chaudhry, A., Gordo, A., Dokania, P., Torr, P., & Lopez-Paz, D. (2020). Using hindsight to anchor past knowledge in continual learning. *arXiv preprint arXiv:2002.08165, 2*(7).

Chowdhury T., Holbrook J., Rannikmäe M. (2020). Addressing Sustainable Development: Promoting Active Informed Citizenry through Trans-Contextual Science Education. *Sustainability*. *12*(8):3259. https://doi.org/10.3390/su12083259

Claxton, G. & Carr, M. (2004). A framework for teaching learning: The dynamics of disposition. Early Years. 24. 87–97. 10.1080/0957514032000179089 8.

Collie, R., & Martin, A. (2016). Adaptability: An Important Capacity for Effective Teachers. *Educational Practice and Theory, 38*. 27–39. 10.7459/ept/38.1.03.

Collins, M., & An, S. (2010). The impact of global warming on the tropical Pacific Ocean and El Nino. *Nature Geoscience, 3*(6), 391–397.

Constantinou, C., Hadjilouca, R. & Papadouris, N. (2010). Students' epistemological awareness concerning the distinction between science and technology. *International Journal of Science Education, 32*(2), 143–172.

Cvetković, V., Öcal, A., & Ivanov, A. (2019). Young adults' fear of disasters: A case study of residents from Turkey, Serbia and Macedonia. *International Journal of Disaster Risk Reduction,* 35, 101095.

David, D., & Rangaswamy, D. (2014). Forecasting of cyclone using multi-temporal change detected satellite images. 2014 IEEE International Conference on Computational Intelligence and Computing Research.
https://doi.org/10.1109/iccic.2014.7238301

Davidson, R., & Shah, H. (1997). An urban earthquake disaster risk index. Standford University: John A. Blume Earthquake Engineering Center. *Earthquake Spectra*, *13*(2), 211–223.

Dean, B. (2015). Comment on 'Quantifying the consensus on anthropogenic global warming in the scientific literature'. Environ. Res. Lett. Environmental Research Letters, 039001–039001.

Deren, A., Malara, Z., & Skonieczny, J. (2017). Creative Thinking in Management of Disruptive Technologies. 10.1007/978-3-319-46592-0_16.

DiGironimo, N. (2011). What is technology? Investigating student conceptions about the nature of technology. *International Journal of Science Education, 33*(10), 1337–1352.

Dobber, M., Zwart, R., Tanis, M., & van Oers, B. (2017). Literature review: The role of the teacher in inquiry-based education. *Educational Research Review, 22,* 194–214. doi:10.4028/www.scientific.net/amm.401-403.2256

Douilly, R., Aochi, H., Calais, E., Freed, A. (2015). Three-dimensional dynamic rupture simulations across interacting faults: The Mw7.0, 2010, Haiti earthquake. *Journal of Geophysical Research, 120*(2), 1108–1128.

Dunbar, P. (2007). Increasing public awareness of natural hazards via the Internet. *Natural Hazards 42*(3), 529–536.

Dunnahoe, T. (2016). Ocean-bottom seismographs improve data resolution offshore Australia. *Oil & Gas Journal, 114*(10), 36–41.

Emrich, C., & Cutter, S. (2011). Social Vulnerability to Climate-Sensitive Hazards in the Southern United States. *Weather, Climate, and Society, 3*(3), 193–208.
https://doi.org/10.1175/2011wcas1092.1

Entwistle, N., McCune, V., & Walker, P. (2001). Conceptions, styles, and approaches within higher education: Analytical abstractions and everyday experience. In R. J. Sternberg & L.-f. Zhang (Eds.), *Perspectives on thinking, learning, and cognitive styles* (pp. 103–136). Lawrence Erlbaum Associates Publishers.

Esteban, M., Bricker, J., Arce, R., Takagi, H., Yun, N., Chaiyapa, W., Shibayama, T. (2018). Tsunami awareness: A comparative assessment between Japan and the USA. *Natural Hazards, 93*(3), 1507–1528. https://doi.org/10.1007/s11069-018-3365-1

Estonian Government. (2011). Põhikooli ja gümnaasiumi riiklik õppekava (National curriculum for basic schools and upper secondary schools). Regulation of the Government of the Republic of Estonia, RT I, 14. 01. 2011, No 2.

Fernandes, G., Rodrigues, A., & Ferreira, C. (2017). Conceptions of the Nature of Science and Technology: A Study with Children and Youths in a Non-Formal Science and Technology Education Setting. *Research in Science Education, 48*(5), 1071–1106. doi:10.1007/s11165-016-9599-6

Fensham, P. (2009). The link between policy and practice in science education: The role of research. *Science Education, 93*(6), 1076–1095. doi:10.1002/sce.20349

Gaiha, R. (2007). Measuring Vulnerability to Natural Hazards: Towards Disaster Resilient Societies edited by Jörn Birkmann. *Development and Change, 38*.962–964. 10.1111/j.1467-7660.2007.00441_5.x.

Garcia, C., & Fearnley, C. (2012). Evaluating critical links in early warning systems for natural hazards. *Environmental Hazards, 11*(2), 123–137.

Gershman, S., Blei, D., Niv, Y. (2010). Context, learning, and extinction. *Psychology Review, 117*(1):197–209. https://doi.org/10.1037/a0017808. PMID: 20063968.

Gilbert, F., Daffern M., Talevski D., Ogloff J. (2013). The Role of Aggression-Related Cognition in the Aggressive Behavior of Offenders: A General Aggression Model Perspective. *Criminal Justice and Behavior. 40*(2): 119–138. doi:10.1177/0093854812467943

Gilbert, J. (2006). On the nature of “context” in chemical education. *International Journal of Science Education., 28*(9), 958.

Gould, D., & Carson, S. (2008). Life skills development through sport: Current status and future directions. *International review of sport and exercise psychology, 1*(1), 58–78.

Govender, N., & Zulu, D. (2017). Natural Sciences Junior High School Teachers’ Understanding of the Nature of Science and its impact on their planning of lessons. *Journal of Baltic Science Education, 16*(3), 366–378.

Gupta, P., & Sharma, Y. (2019). Nurturing scientific creativity in the science classroom. *Resonance*, *24*(5), 561–574.

Guthrie, J., Wigfield, A., Barbosa, P., Perencevich, K., Taboada, A., Davis, M., Scafiddi, N., & Tonks, S. (2004). Increasing Reading Comprehension and Engagement Through Concept-Oriented Reading Instruction. *Journal of Educational Psychology, 96*, 403–423.

Hale, A., Ricotta, D., Freed, J., Smith, C., & Huang, G. (2019). Adapting Maslow’s hierarchy of needs as a framework for resident wellness. *Teaching and learning in medicine, 31*(1), 109–118.

Hodson, D., & Wong, S. (2017). Going beyond the consensus view: Broadening and enriching the scope of NOS-oriented curricula. *Canadian Journal of Science, Mathematics and Technology Education, 17*(1), 3–17. https://doi.org/10.1080/14926156.2016.1271919

Holbrook, J., & Rannikmäe, M. (2007). The Nature of Science Education for Enhancing Scientific Literacy. *International Journal of Science Education,* 1347–1362.

Holbrook, J., & Rannikmäe, M. (2010). Contextualisation, de-contextualisation, re-contextualisation – A science teaching approach to enhance meaningful learning for scientific literacy. In I. Eilks & B. Ralle (eds.), Contemporary science education (pp. 69–82). Aachen: Shaker.

Holbrook, J., & Rannikmäe, M. (2014). The philosophy and approach on which the PROFILES project is based. *Center for Educational Policy Studies Journal, 4*. 9–29.

Holdeman, E. (2014). 'Technology Plays an Increasing Role in Emergency Management'. Available at: http://www.govtech.com/em/training/Technology-Increasing-Role-Emergency-Management.html. [Accessed: 21 October 2020]

Hui, E., & Tsang, S. (2012). Self-determination as a psychological and positive youth development construct. *The Scientific World Journal,* 2012.

Iovine, G., Sheridan, M., & Gregorio, S. (2006). Computer simulation of natural phenomena for hazard assessment. *Computers & Geosciences, 32*(7), 859–860. doi:10.1016/j.cageo.2005.12.001

Irvine, J. (2017). A Comparison of Revised Bloom and Marzano's New Taxonomy of Learning. *Research in Higher Education Journal,* 33.

Jankaew, K., Atwater, B., Sawai, Y., Choowong, M., Charoentitirat, T., Charoentitirat, T., Martin, M., Prendergast, A. (2008). Medieval forewarning of the 2004 Indian Ocean tsunami in Thailand. *Nature, 455*(7217), 1228–1231.

Jin, D., & Yang, J. (2013). The Nature of Science and the Limitations of Science on Narrow Sense. *Applied Mechanics and Materials,* 401–403, 2256–2261.

Johnson, J., Macalalag, A. & Dunphy, J. (2020). Incorporating socioscientific issues into a STEM education course: exploring teacher use of argumentation in SSI and plans for classroom implementation. *Disciplinary and Interdisciplinary Science Education Research 2*, 9. https://doi.org/10.1186/s43031-020-00026-3

Jones, L., Jaspars, S., Pavanello, S., Ludi, E., Slater, R., Grist, N., & Mtisi, S. (2010). Responding to a changing climate: Exploring how disaster risk reduction, social protection and livelihoods approaches promote features of adaptive capacity.

Kabilan, M. (2000). Creative and critical thinking in language classrooms. The Internet TESL Journal, 6(6). Retrieved 2015, November 5 from http://itselj.org/ Techniques/ Kabilian-CriticalThinking.html.

Kervinen, A., Roth, W., Juuti, K., & Uitto, A. (2020). The resurgence of everyday experiences in school science learning activities. *Cultural Studies of Science Education,* 1–27.

Kim, H., Woosnam, K., & Aleshinloye, K. (2014). Evaluating Coastal Resilience and Disaster Response: The Case of Galveston and Texas Gulf Counties following Hurricane Ike. *Coastal Management, 42*(3), 227–245.

Kotkas, T., Holbrook, J., & Rannikmäe, M. (2017). A theory-based instrument to evaluate motivational triggers perceived by students in stem career-related scenarios. *Journal of Baltic Science Education, 16*(6), 836–854.

Knapp, N. (2019). The shape activity: Social constructivism in the psychology classroom. *Teaching of Psychology*, *46*(1), 87–91.

Kropivnitskaya, Y. (2016). "Using Physical and Social Sensors in Real-Time Data Streaming for Natural Hazard Monitoring and Response". Electronic Thesis and Dissertation Repository. 4079. https://ir.lib.uwo.ca/etd/4079

Kubieck, J. (2005). Inquiry-based learning, the nature of science, and computer technology: New possibilities in science education. *Canadian Journal of Learning and Technology/La revue canadienne de l'apprentissage et de la technologie*, *31*(1).

Lederman, N. (2007). Nature of science: Past, present, and future. In S.K. Abell, & N.G. Lederman (Eds.). Handbook of research in science education (pp 831–879). Mahwah, New Jersey: Lawrence Erlbaum Publishers.

Lederman, N., & Abd-El-Khalick, F. (1998). Avoiding de-natured science: Activities that promote understandings of the nature of science. In The nature of science in science education (pp. 83–126). Springer, Dordrecht.

Lerner-Lam, A. (2007). Assessing global exposure to natural hazards: Progress and future trends. *Environmental Hazards, 7*(1), 10–19.
Li, J., Dong, W., Oenema, O., Chen, T., Hu, C., Yuan, H., & Zhao, L. (2019). Irrigation reduces the negative effect of global warming on winter wheat yield and greenhouse gas intensity. *Science of The Total Environment,* 646, 290–299. https://doi.org/10.1016/j.scitotenv.2018.07.296
Lindahl, M., Folkesson, A., & Zeidler, D. (2019). Students' recognition of educational demands in the context of a socioscientific issues curriculum. *Journal of Research in Science Teaching, 56*(9), 1155–1182. doi:10.1002/tea.21548
Liou, P. (2015). Developing an Instrument for Assessing Students' Concepts of the Nature of Technology. *Research in Science & Technological Education, 33*(2), 162–181.
Lonn, M., & Dantzler, J. (2017). A practical approach to counseling refugees: Applying Maslow's hierarchy of needs. *Journal of Counselor Practice, 8,* 61–83. https://doi.org/10.22229/olr789150
Loucks, D., Stedinger, J., Stakhiv, E. (2006). Individual and Societal Responses to Natural Hazards. *Journal of Water Resources Planning and Management, 132*(5), 315–319.
Loucks-Horsley, S., Stiles, K., Mundry, S., Love, N., & Hewson, P. (2009). Designing professional development for teachers of science and mathematics. Corwin press.
Lovhølt, F., Setiadi, N., Birkmann, J., Harbitz, C., Bach, C., Fernando, N., & Nadim, F. (2014). Tsunami risk reduction – are we better prepared today than in 2004*? International Journal of Disaster Risk Reduction, 10*, 127–142.
Mahamuni, R., Kalyani, K., & Yadav, P. (2015). A simplified approach for making human values central to interaction design. *Procedia Manufacturing, 3*, 874–881.
Manfré, L., Hirata, E., Silva, J., Shinohara, E., Giannotti, M., Larocca, A., & Quintanilha, J. (2012). An analysis of geospatial technologies for risk and natural disaster management. ISPRS *International Journal of Geo-Information, 1*(2), 166–185.
Maslow, A. (1943). A theory of human motivation. *Psychological Review, 50*(4), 370–396. https://doi.org/10.1037/h0054346
McComas, W. (1998). The Principal Elements of the Nature of Science: Dispelling the Myths. The Nature of Science in Science Education Science & Technology Education Library, 53–70. https://doi.org/10.1007/0-306-47215-5_3
McIvor, D., & Paton, D. (2007). Preparing for Natural Hazards: Normative and Attitudinal Influences. *Disaster Prevention and Management. 16.* 79–88. https://doi.org/10.1108/09653560710729839.
MEXT. (2009). Koutougakko gakusyu shido yoryo (Course of study for junior and senior high schools). Kyoto: Higashiyama Shobou.
Mishra, K. (2014). Social Constructivism and Teaching of Social Science. *Journal of Social Studies Education Research. 5.* https://doi.org/10.17499/jsser.22283.
MOFA. (2020). Disaster prevention. Retrieved March 14, 2021, from: https://www.mofa.go.jp/policy/disaster/21st/2.html
Moore, D. (2005). Suffering for territory: Race, place, and power in Zimbabwe. Duke University Press.
Morshead, R. (1965). "Taxonomy of Educational Objectives Handbook II: Affective Domain." *Studies in Philosophy and Education* 4(1): 164–170. http://hdl.handle.net/2027.42/43808
Munene, P. (2019). An Assessment of Fire Disaster Management in Urban Areas: a Case Study of Nairobi City County, Kenya (Doctoral dissertation, University of Nairobi).

Multihazard Mitigation Council (2018). Principal Investigator Porter, K.; co-Principal Investigators Scawthorn, C.; Huyck, C.; Investigators: Eguchi, R., Hu, Z.; Reeder, A; Schneider, P., Director, MMC. National Institute of Building Sciences, Washington, D.C. www.nibs.org

Najafi, M., Ardalan, A., Akbarisari, A., Noorbala, A., Elmi H. (2017). The theory of planned behavior and disaster preparedness. *PLOS Currents Disasters. 6*(1) https://doi.org/10.1371/currents.dis.4da18e0f1479bf6c0a94b29e0dbf4a72.

National Research Council (NRC). (2012). A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. Washington, DC: The National Academies Press. https://doi.org/10.17226/13165.

NGSS. (2013). Next Generation Science Standards: For states, by states. Washington, D.C.: National Academies Press, 170.

Njura, H., Kaberia, I., & Taaliu, S. (2020). Effect of agricultural teaching approaches on skills development for food security: a case of secondary schools in Embu County, Kenya. The *Journal of Agricultural Education and Extension, 26*(3), 239–252.

NSTA. (2020). About the Next Generation Science Standards. Retrieved from https://ngss.nsta.org/About.aspx

Obasi, G. (1994). WMO's role in the international decade for natural disaster reduction. *Bulletin of the American Meteorological Society, 75*(9), 1655–1661.

OECD. (2019). Programme for International Student Assessment. https://www.oecd.org/pisa/

Oyao, S., Holbrook, J., Rannikmäe, M. & Pagunsan, M. (2015). A Competence-based Science LearningFramework illustrated through the Study of Natural Hazards and Disaster Risk Reduction. *International Journal of Science Education, 37*(14), 2237−2263.

P21 (2008). Moving Education Forward. Partnership for 21st Century Skills (P21).

Pampanin, S. (2015). Towards the "Ultimate Earthquake-Proof" Building: Development of an Integrated Low-Damage System. Perspectives on European Earthquake Engineering and Seismology. *Geotechnical, Geological and Earthquake Engineering,* 321–358. doi:10.1007/978-3-319-16964-4_13

Peduzzi, P., Dao, H., Herold, C., & Mouton, F. (2009). Assessing global exposure and vulnerability towards natural hazards: The Disaster Risk Index. *Natural Hazards and Earth System Science, 9*(4), 1149–1159.

Pellegrino, J., (2012). Education for life and work: Developing transferable knowledge and skills in the 21st century. Washington, D.C.: The National Academies Press.

Phillips, M., & Schmidlin, T. (2013). The current status of lightning safety knowledge and the effects of lightning education modes on college students. *Nat Hazards Natural Hazards,* 1231–1245.

Piaget, J. (1971). The theory of stages in cognitive development. In D. R. Green, M. P. Ford, & G. B. Flamer, Measurement and Piaget. McGraw-Hill.

Pisano, F. (1998). About the international decade for natural disaster reduction. La Houille Blanche, (2), 68–69.

Popham, J. (2009). Assessment Literacy for Teachers: Faddish or Fundamental? *Theory Into Practice, 48:*1, 4–11, https://doi.org/10.1080/00405840802577536

Popham, W. (2007). Instructional Insensitivity of Tests: Accountability's Dire Drawback. *Phi Delta Kappan. 89*(2):146–155. doi:10.1177/003172170708900211

Powell, K., & Kalina, C. (2009). Cognitive and Social Constructivism: Developing Tools for an Effective Classroom. *Education.* 130.

Prayogi, S. & Yuanita, L. (2018). Critical inquiry based learning: A model of learning to promote critical thinking among prospective teachers of physic. *Journal of Turkish Science Education, 15*(1), 43–56.

Rabinovich, A., Geist, E., Fritz, H., & Borrero, J. (2015). Introduction to "Tsunami Science: Ten Years After the 2004 Indian Ocean Tsunami. Volume I." Pure and Applied Geophysics, 172(3–4), 615–619. https://doi.org/10.1007/s00024-015-1038-5

Raka, I., & Astawa, M. (2014). State-of-the-Art Report on Partially-prestressed Concrete Earthquake-resistant Building Structures for Highly-seismic Region. *Procedia Engineering, 95*, 43–53. doi:10.1016/j.proeng.2014.12.164

Rattien, S. (1990). The role of the media in hazard mitigation and disaster management. Disasters. (1):36–45. https://doi.org/10.1111/j.1467-7717.1990.tb00970.x. PMID: 20958692.

Rosenkoetter, M., Covan, E., Cobb, B., Bunting, S., & Weinrich, M. (2007). Perceptions of Older Adults Regarding Evacuation in the Event of a Natural Disaster. *Public Health Nursing, 24(*2), 160–168. https://doi.org/10.1111/j.1525-1446.2007.00620.x

Rotherham, A., & Willingham, D. (2010). 21st-century" skills. *American Educator, 17*(1), 17–20.

Ryan, R., & Deci, E. (2002). Overview of self-determination theory: An organismic-dialectical perspective. In E. L. Deci & R. M. Ryan (Eds.), *Handbook of self-determination research* (pp. 3–33). University of Rochester Press.

Sadler, T., & Zeidler, D. (2005). Patterns of Informal Reasoning in the Context of Socio-scientific Decision Making. *Journal of Research in Science Teaching, 42*, 112–138.

Santos, A., Tavares, A., & Emidio, A. (2014). Comparative tsunami vulnerability assessment of an urban area: An analysis of Setúbal city, Portugal. *Applied Geography, 55*, 19–29.

Satterthwaite, D., McGranahan, G., & Tacoli, C. (2010). Urbanization and its implications for food and farming. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences. 365*(1554), 2809–2820. doi:10.1098/rstb.2010.0136.

Schneider, R., Plasman K. (2011). Science Teacher Learning Progressions: A Review of Science Teachers' Pedagogical Content Knowledge Development. *Review of Educational Research. 81*(4):530–565. doi:10.3102/0034654311423382

Semilarski, H., Soobard, R., Holbrook, J., & Rannikmäe, R. (2021). *Interdisciplinary Journal of Environmental and Science Education 17*(1), e2227.

Shaw, R. (2020) Thirty Years of Science, Technology, and Academia in Disaster Risk Reduction and Emerging Responsibilities. *International Journal of Disaster Risk Science 11*, 414–425. https://doi.org/10.1007/s13753-020-00264-z

Shea, N., & Duncan, R. (2013). From theory to data: The process of refining learning progressions. *Journal of the Learning Sciences, 22*(1), 7–32.

Sheldrake, R., Mujtaba, T., & Reiss, M. (2017). Science teaching and students' attitudes and aspirations: The importance of conveying the applications and relevance of science. *International Journal of Educational Research, 85,* 167–183. https://doi.org/10.1016/j.ijer.2017.08.002

Shi P. (2019). Hazards, Disasters, and Risks. Disaster Risk Science, pp. 1–48. https://doi.org/10.1007/978-981-13-6689-5_1

Simpson, E. (1972). The Classification of Educational Objectives in the Psychomotor Domain. Gryphon House, Washington DC.

Sims, J., & Baumann, D. (1983). Educational Programs and Human Response to Natural Hazards. *Environment and Behavior, 15*(2), 165.

Siribunnam, S., Nuangchalerm, P. & Jansawang, N. (2014). Socio-scientific Decision Making in the Science Classroom. *International Journal for Cross-Disciplinary Subjects in Education, 5(*4): 1777–1782.

Sivakumar, M. (2005). Impacts of Natural Disasters in Agriculture, Rangeland and Forestry: An Overview. In Natural Disasters and Extreme Events in Agriculture; Sivakumar, M., Motha, R.P., Das, H.P., Eds.; Springer: Berlin/Heidelberg, Germany; New York, NY, USA, pp. 1–22.

Sormunen, K., Keinonen, T., & Holbrook, J. (2014). Finnish Science Teachers' Views on the Three Stage Model. *Science Education International, 25*, 43–56.

Spencer, R. (2007). How Serious is the Global Warming Threat? Soc Society, 45–50.

Stephens, A., Fonger, N., Strachota, S., Isler, I., Blanton, M., Knuth, E., & Murphy-Gardiner, A. (2017). *A learning progression for elementary students' functional thinking. Mathematical Thinking and Learning, 19*(3), 143–166.

Stephens, S., Adams, M., Handmer, J., Kearns, F., Leicester, B., Leonard, J., & Moritz, M. (2009). Urban–wildland fires: how California and other regions of the US can learn from Australia. *Environmental Research Letters, 4*(1), 014010. https://doi.org/10.1088/1748-9326/4/1/014010

Stone, R. (2005). A race to beat the odds. *Science, 307*, 502–504.

Stuckey, M., Hofstein, A., Malmok-Naaman, R., & Eilks, I. (2013). The meaning of 'relevance' in science education and its implications for the science curriculum. *Studies in Science Education, 49*(1), 1–34.

Surya, E., & Putri, F. (2017). Improving mathematical problem-solving ability and self-confidence of high school students through contextual learning model. *Journal on Mathematics Education, 8*(1), 85–94.

Sword-Daniels, V., Eriksen, C., Hudson-Doyle, E., Alaniz, R., Adler, C., Schenk, T., & Vallance, S. (2018). *Embodied uncertainty: living with complexity and natural hazards. Journal of Risk Research, 21*(3), 290–307.

Tara, N., Irshad, M., Khan, M., Yamin, M., & Rizwan, M. (2014). Factors influencing adoption of Islamic banking: A study from Pakistan. J*ournal of Public Administration and Governance, 4*(3), 352–367.

Tytler, R. (2007). Re-Imagining Science Education Engaging Students in Science for Australia's Future. *Australian Education Review, 51*, 1–77.

UNICEF. (2012). Disaster Risk Reduction in School Curricula: Case Studies from Thirty Countries. Available online: http://unesdoc.unesco.org/images/0021/002170/217036e.pdf (accessed on 20 October 2020).

United Nations General Assembly Session 44 Resolution 236. A/RES/44/236 22 December 1989. Retrieved 2008-09-18.

United Nations Office for Disaster Reduction (2009). UNISDR Terminology on Disaster Risk Reduction. Retrieved from: Geneva, May 2009. http://www.unisdr.org/we/inform/terminology.

United Nations University—Institute for Environment and Human Security. World Risk Report. (2016). https://collections.unu.edu/eserv/UNU:5763/WorldRiskReport2016_small_meta. pdf (accessed on 16 September 2020).

United States Government. (1992). Japan – Tokyo Declaration On Global Partnership With The US. Retrieved November 20, 2020, from:
https://tcc.export.gov/Trade_Agreements/All_Trade_Agreements/exp_005589.asp

Valdmann, A., Holbrook, J., & Rannikmäe, M. (2020). Defining teacher ownership: A science education case study to determine categories of teacher ownership. *Journal of Baltic Science Education, 19*(4), 659–674. https://doi.org/10.33225/jbse/20.19.659

van Aalst, J. (2009). Distinguishing knowledge-sharing, knowledge-construction, and knowledge-creation discourses. *International Journal of Computer-Supported Collaborative Learning, 4*(3), 259–287.
Velev, D., & Zlateva, P. (2017). Virtual reality challenges in education and training. International. Journal of Learning and Teaching, 3(1), 33–37.
Vygotsky, L. (1978). Mind in society: The development of higher psychological processes Cambridge, Mass.: Harvard University Press.
Wachinger, G., Renn, O., Begg, C., & Kuhlicke, C. (2013). The risk perception paradox – implications for governance and communication of natural hazards. *Risk analysis, 33*(6), 1049–1065.
Wang, Z., & Ye, X. (2019). Space, time, and situational awareness in natural hazards: a case study of Hurricane Sandy with social media data. *Cartography and Geographic Information Science, 46*(4), 334–346.
Wiles, J. (2008). Leading curriculum development. Corwin press.
Wisner, B., Blaikie, P., Blaikie, P., Cannon, T., & Davis, I. (2004). *At risk: natural hazards, people's vulnerability and disasters, 2(2)*. Psychology Press.
WTO. (1998). Handbook on natural disaster reduction in tourist areas. Madrid: World Tourism Organization.
Zeidler, D., Herman, B., & Sadler, T. (2019). New directions in socioscientific issues research. *Disciplinary and Interdisciplinary Science Education Research, 1,* 11. https://doi.org/10.1186/s43031-019-0008-7
Zoller, U., & Pushkin, D. (2007). Matching Higher-Order Cognitive Skills (HOCS)-promoting goal with problem-based laboratory practice in a freshman organic chemistry course, *Chemical Education Research and Practice*, *8*(2), 153–171.

SUMMARY

We live in a scientific and technological world, with major developments continually taking place in our lives. Despite this, science and technology, for the most part, are not able to predict natural hazards. Nor has science and technology been able to play any meaningful role in eliminating natural hazards, both tectonic and meteorological. This is clearly a concern, especially as there is an increase in frequency and magnitude of meteorological natural hazards (Emrich & Cutter, 2011; Li et al., 2019), resulting from issues such as rising global average temperatures (Spencer, 2007; Dean, 2015) and a trend towards urbanization (Satterthwaite, McGranahan, & Tacoli, 2010).

Natural phenomena in the form of tsunamis, earthquakes, hurricanes and even lightning are events that can lead to loss of life. There has been an increase in frequency and magnitude of such tectonic and meteorological natural hazards (Emrich & Cutter, 2011; Li et al., 2019), resulting from issues such as rising global average temperatures (Spencer, 2007; Dean, 2015) and a trend towards urbanization (Satterthwaite, McGranahan, & Tacoli, 2010). Awareness of the potential dangers from natural hazards (NH) is a first step towards reducing risks related to natural disaster reduction hazards (NDR). The raising of such an awareness is thus seen as an important education component (NGSS, 2013). However, there is a potential concern that the teaching does not go far enough in recognizing the importance of including coverage related to learning associated with the increasing frequency and magnitude of natural hazards and the need to include the transference of learning to new situations, important for taking responsible actions in the event of a natural hazard. Some countries (for example, Japan, Philippines and Indonesia) have included responsible actions to take in the event of a natural hazard in the state curriculum document (Japanese Curriculum – MEXT, 2009). However, in the past, little research regarding the awareness of natural hazards has been undertaken (Dunbar, 2007). Furthermore, the role of science education preparing students in making decisions in the face of natural hazards is poorly understood and curricula pay little attention to the need to undertake, not only appropriate or meaningful actions, but these actions need to be responsible with regard to the actual situation. This is a dilemma, as classroom education is ill prepared to deal with real situations as they happen and needs to rely on the development of competences that can be transferred to new situations. This requires attention to a meaningful learning progression and teachers being aware of the learning needs, plus a society where the awareness and preparedness to act is an accepted expectation.

The aim of this research is to investigate the attention being paid to relating the teaching and learning associated with natural hazards and to promote the taking of responsible behavioral actions against the negative impacts of natural hazards. In so doing, this research sees the need to re-examine teaching/learning models suitable for science and natural hazard education, based on educational theories as well as exploring the potential creation of an awareness and pre-

paredness index against natural hazard situations. The research further seeks to determine student and teacher conceptualization in recognizing the role of NOS, NOT as well as beliefs, attitudes and values, to develop self-determination with respect to NDR in natural hazard occurrences.

This research was carried out as a four level process, thereby:

(1) devising a theoretical education model to support the teaching of science subjects, building on existing taxonomies and theories, which seeks to enhance competences in terms of values, skills, attitudes and knowledge through pre-existing events and experiences. Such a model intends to be meaningfully in line with teaching and learning approaches. From a knowledge base, these encompass the development of problem solving and decision making abilities and the model recognizes the ultimate need to support teachers in meaningful teaching approaches that can enhance the development of responsible behavioral actions in the face of natural hazards, The model recognizes a progressive conceptualization of the nature of science, as well as technology ideas, developed implicitly and explicitly to address meaningful contexts in natural hazard teaching/learning;

(2) establishing a countrywide awareness and preparedness index (API), based on an awareness factor based on vulnerability and a preparedness factor based on the impact of education. The API is devised with a view towards identifying the impact of a country's education on the realization of natural hazard awareness and preparedness towards natural hazard disaster reduction (NDR);

(3) testing students' learning in science education, based in particular through natural hazard teaching involving attributes promoted through the model using a validated instrument and focusing on student gains in the desired learning attributes associated with the devised model. This is undertaken through data collection in three countries with a view towards determining the extent to which students are able to handle natural hazard situations and take responsible behavioral action. The test is based on student learning with respect to an appreciation of the nature of science, the nature of technology and the enhancement of meaningful student dispositions especially through natural hazard events and disaster mitigation;

(4) determining competences towards teaching associated with natural hazards and natural hazard disaster reduction, in line with the developed model. This is undertaken with a view towards determining teacher perceptions and opinions with respect to their preparedness to promote, via an appropriate education focus, meaningful student learning. The teaching is associated with the students being able to put forward responsible behavioral actions in the face of natural hazards.

A World Risk Report (UNU, 2016) encompassing a World Risk Index (WRI), published comparison data of countries on a global scale (Birkmann et al., 2014) by focusing on the interaction of physical hazards and the vulnerability to exposed elements. This is based on the general notion that the intensity of an extreme natural event is not the only relevant factor in assessing a disaster risk. Nevertheless, this thesis recognizes the WRI is insufficient in and of itself, because the relationships between the WRI subcomponents are not extensively explored. As the need for education, the media and Governmental stipulations to interrelate, an index relating to a country's awareness of, as well as preparedness for, dealing with natural hazards situations is put forward in this thesis. The index is based on relationships between WRI subcomponents and an education factor, created independent of WRI. In this thesis an analysis, based on 30 countries, is presented drawing attention to not only the levels of awareness faced by a country, but also the degree to which the education potential can play a preparedness role in mitigating against loss of life in natural hazard disaster situations.

The value of the role played by education in natural hazard disaster mitigation, clearly depends on the education focus and emphasis. While the undertaking of responsible behavioral actions is very desirable, an education model needs to put forward appropriate steps forming a progression toward such a goal. Such a model, related to science education in general, can be clearly expected to build on educational learning taxonomies and theories (Maslow, 1943; Bloom, 1956; Piaget 1971), but also needs to encompass a meaningful learning progression and encompass the development of competences. In ensuring the model offers appropriate guidance for teachers, it is visualized that there is a need to go beyond a theoretical portrayal and to include a focus on the teaching/learning approach. In this thesis, such a model is based on a three level approach, put forward in the literature (Holbrook & Rannikmäe, 2010) to promote a motivational teaching focus, as the initial level. Further levels detail an approach to the development of sound conceptual science and the promotion of argumentation skills, related to socio-scientific reasoning, seen as an important prerequisite for an ultimate extension to a fourth level, the promotion of skills towards the putting forward of responsible behavioral actions. The model is, however, not seen as complete without the need to pay careful attention to attitudes and beliefs towards natural hazard and progressive conceptualization of the nature of science and the nature of technology.

The goal of [P1] and the devising of an educational model is to address a lack of a suitable taxonomy by which to guide teaching and learning with respect to NH/NDR. Based on this, the student test instrument is seen as novel and includes a focus on determining students' conceptualization of the nature of science (NOS) (McComas, 1998; Lederman, 2007), an-associated nature of technology (NOT) (Constantinou et al., 2010), strong attention to the development of dispositions (Claxton & Carr, 2004; Carroll, 2012) and promotion of cross cutting concepts (i.e. 21st century skills) (P21, 2008; Pellegrino, 2012; NRC, 2012; NGSS, 2013). The instrument also focused on identifying ability to recognize, or put forward, responsible behavioral actions (Oyao et al., 2015) plus addresses student experiences related with natural hazards, as well as their perception of risk, based on responses from students in Estonia, United States and Japan. The test, based largely on a revised model from that in [P1], is developed within the field of science education, but specifically orientated towards the teaching and learning of natural hazards (NH). The novel feature of the test is that students interact with one of four-contextual scenarios, linking subject learning with ethical, moral and other dilemmas, plus personal educational competence development. As such, the tests relate to determining progression in cognitive, dispositions and action learning toward the making of responsible decisions. The thesis seeks to address attainment in the US, based on NGSS (NGSS, 2013). Although NGSS does mention natural hazard disaster reduction (NDR), the potential concern is that the standards do not go far enough in recognizing the importance of coverage related to learning associated with the increasing frequency and magnitude of natural hazards and the need to include the transference of learning to new situations, important for taking responsible actions in the event of a natural hazard. Nevertheless, NGSS does include NOS, NH, NDR and the development of cross cutting concepts. In Estonia and Japan, the curricula do not address specifically natural hazards (MEXT, 2009; Estonian Government, 2011).

An awareness and preparedness index (API), as derived in this thesis, is a countrywide index irrespective of the differences in the sources of potential risks posed by natural hazards across the country (Davidson & Shah, 1997). Such a countrywide index can be argued to be meaningful in a small country, such as Estonia, especially as the population exposure to natural hazards is relatively uniform, but less so in large countries, although ease of travel within a country can be seen to bring an element of unity to facing natural hazards. In this thesis, a major rationale in promoting preparedness is in enabling students to develop responsible behavioral actions in the case of NDR. The API is seen as having greater value than a NHF-EF indicator [P2]. The API is thus put forward as a valid and reliable index towards illustrating the relationship between awareness and preparedness, based on data from selected countries in Asia, Europe and the Americas. Further, it enables a move away from risk and towards embracing awareness and preparedness, which is more clearly associated with science teaching and teaching NDR through real world experiences and everyday contexts, relevant to students. Through the API, the relationships between natural hazards and education are interrelated, increasing the validity of the API through graphically illustrated lines of regression, which show a strong, positive relationship between education and the inverse of (a) vulnerability, (b) susceptibility, (c) the lack of coping capacities, (d) the lack of adaptive capacities, as well as (e) a combination of the lack of coping and adaptive capacities. From the latter, the calculated index is established for 30 countries, ranging from 103.5 to 320.0 and shows that while Estonia and US are similarly placed, the index for Japan is somewhat higher, indicating that Japan is relatively more aware and prepared in dealing with natural hazards.

In [P1], a student pilot test is devised and validated based on the model put forward in Figure 1. The pilot test, based on outcomes, shows that students tend to indicate they had experienced at least one form of natural hazard, mostly of a meteorological kind, whilst tsunamis were rarely experienced by any student. Students indicate that they experience lightning as the most common natural hazard, yet it is feared the least across all samples. This is interesting because the opposite is stated for tsunamis and suggests a connection, whereby natural hazards that are experienced the least, are feared the most, and the reverse is true where natural hazards that are experienced the most, are feared the least.

The ultimate goal of the model is to foster the development of responsible behavioral action during the event of a natural hazard or disaster. The pilot study outcomes indicate that it is a base for the main student test in [P3]. Nevertheless, a revised educational model, considered from a theoretical perspective (Figure 1) and a teaching orientation (Figure 2), is shown to encompass an expected teaching progression forming a base for developing the student test as in [P3] for learning associated with conceptualization of natural hazards and disaster reduction.

The student test in [P3] addresses conceptualizations of NOS NOT and the value of including dispositions in promoting learning towards responsible behavioral action. Items especially seek to address the matching of NOS, NOT and disposition with responses to both positive and negative responsible behavioral situations, in an effort to identify potential links between NOS, NOT and dispositions and responsible behavioral actions (Oyao et al., 2015). While the literature views conceptualization of NOS and NOT as important for science education (McComas, 1998; Lederman 2007; Fernandes, Rodrigues, & Ferreira, 2017), responses on NOS and NOT, from all three countries, are generally low and suggest an area of concern. This is in line with literature findings (DiGironimo, 2011; Liou, 2015). The outcomes from [P3] also indicate that students, in general, seem to find it difficult to respond to, and give, responsible behavioral actions. This applies for all four natural hazard situations utilized in the test and for students across all countries/regions. In general, the percentage of acceptable behavioral actions was low (about 50% responsible behavioral action across Hurricane, Lightning, Earthquake and Tsunami scenarios per country).

Overall responses to the teacher questionnaire, endorsed by follow-up interviews, indicate that teachers felt it was of value for students to be able to learn how to act responsibly during an imaginary natural disaster in ways that reduced risks and saved lives. The learning progression put forward in Figure 1 and Figure 2 was recognized as potentially an effective frame for teachers to promote student learning, associated with transference of learning to put forward responsible behavioral actions. The imaginary situations were seen as useful by teachers. Nevertheless, it seems that overall teachers themselves are unprepared to teach responsible behavioral action perhaps because teachers themselves do not possess the necessary competence (such as decision making) to effectively teach the putting forward of responsible behavioral actions.

Teacher interviewees perceive the teaching emphasis in Figure 2, promoting a teaching/learning progression by encompassing the three level model, (conceptualization, de-contextualization, re-contextualization) as suitable although they suggest that such as teaching approach needs more teaching time, because much greater emphasis is placed on teaching and learning of NDR. In general, the devised educational model, considered from a theoretical perspective (Figure 1) and a teaching orientation (Figure 2), encompassing the expected learning progression, is seen as appropriate for developing the student test as in [P3]. Teachers suggest that it's important to place an emphasis on NDR, but they do not actually do this. The excuse seems to be that there is not enough teaching time. The teacher interviewees seem to endorse the teachers' belief that there is a need for an increased emphasis on NDR in NGSS, as evidenced by the positive responses given in the teacher questionnaire for Items 18 and 19. Such findings suggest that there is a potential need for US teachers to give greater attention to the inclusion of NDR within the existing NGSS standards, so that taking responsible actions, particularly in the event of NDR in a natural disaster occurrence, is included in any future versions of NGSS.

SUMMARY IN ESTONIAN

Õpetajate ja õpilaste loodusõnnetustealane teadlikkus ja valmisolek ning hariduse roll loodusõnnetuste mõju leevendamisel

Vaatamata tormilisele arengule ei suuda teadus ja tehnoloogia mitmesuguseid loodusõnnetusi kõrvaldada ning nendega kaasnevaid inimohvreid vältida. See on murettekitav, sest meteoroloogiliste ohtude sagedus ja ulatus on suurenenud, põhjustatuna globaalsest soojenemisest ja linnastumise kasvust. Võimalike loodusõnnetuste teadvustamine on esimene samm, kuidas vähendada nendega seotud riske. Teadlikkuse suurendamine on aga valdavalt loodusteadusliku hariduse ülesanne, seejuures sõltub õpetamisest, kas õpilastel on olemas vajalikud teadmised, kuidas kriisiolukordades käituda, ja kas nad on valmis neid rakendama. Sel eesmärgil on mõned riigid (nt Jaapan, Filipiinid ja Indoneesia) lisanud riiklikku õppekavva vastutustundlikud tegevused tegutsemiseks loodusõnnetuste korral.

Kuigi vajadus kõnealuse teemaga tegelemise järele suureneb üha, on seni loodusõnnetuste teadvustamist vähe uuritud. Veelgi enam, õpilaste ettevalmistamise rolli loodusõnnetuste korral otsuste langetamisel mõistetakse halvasti ja õppekavades pööratakse vähe tähelepanu vajadusele teha kriisiolukorras sobivaid ja mõttekaid otsuseid ning vastavalt ka käituda. Peamine probleem seisneb selles, et klassiruumis ei valmistata õpilasi tegelike olukordade lahendamiseks piisavalt hästi ette, samuti jääb vajaka ülekantavate pädevuste arendamisest. Probleemi lahendamiseks on tähtis edendada mõtestatud õppimist ja tõhustada õpivajadustest teadlike õpetajate ettevalmistamist, mis võimaldaks kujundada ühiskonda, kus teadlikkus ja tegutsemisvalmidus on aktsepteeritud ootus.

Doktoritöö peamine eesmärk on selgitada riigi tasandil teadlikkust ja valmisolekut tegutseda loodusõnnetuste korral ning otsida viise suurendada võimet vastutustundlikult ja mõtestatult toimida, kasutades teaduspõhiseid teadmisi loodusõnnetuste kohta ning erinevaid võimalusi, sh mobiilirakendusi. Seda on võimalik saavutada eelkõige loodusõpetuse õppimise kaudu, suurendades probleemide lahendamise ja otsuste langetamise võimet ning lähtudes teaduse ja tehnoloogia olemuse mõistlikust kontseptualiseerimisest. Seejuures on oluline võime kasutada õppekavaüleseid oskusi, et tõhustada vastutustundlikule käitumisele toetuvaid meetmeid loodusõnnetuste mõju leevendamisel

Uurimistöö koosnes neljast etapist ja hõlmas järgmisi ülesandeid.

1. Luua loodusõnnetuste suhtes haavatavuse ja hariduse potentsiaalse mõju põhjal loodusõnnetustest teadlikkuse ja nendeks valmisoleku indeks (API), et selgitada välja hariduse mõju loodusõnnetustest teadlikkuse ja nendeks valmisoleku teadvustamisel.
2. Koostada loodusteaduste õpetamise toetamiseks teoreetiline haridusmudel, mis tugineb olemasolevatele taksonoomiatele ja teooriatele ning mis püüab varasemate kogemuste varal suurendada väärtuste, teadmiste, oskuste ja

hoiakutega seotud pädevusi. Selline õpetamise ja õppimise mudel hõlmab probleemide lahendamist ja otsuste langetamist, käsitledes nii loodusseadustest arusaamist kui ka kaudselt ja otsesõnu väljatöötatud tehnoloogiaideid, mis on mõeldud rakendamiseks loodusõnnetuste õpetamisel/õppimisel. Mudel rõhutab vajadust toetada mõtestatud õpetamist, mis võib loodusõnnetuste korral edendada vastutustundlikku käitumist.

3. Töötada välja loodushariduse seisukohalt olulised põhimõtted, mis moodustavad osa kontseptuaalsest mudelist ja mida testitakse valideeritud mõõtevahendiga ning mis keskenduvad etteantud režiimiga seotud soovitud õpitulemustele. Mudel põhineb kolme riigi (Eesti, USA, Jaapani) koolides kogutud ankeetandmetel, mis iseloomustavad, mil määral õpilased suudavad looduslikes ohuolukordades toime tulla ja vastutustundlikult käituda. Kriteeriumiks on õpetamise sisuline kvaliteet, mille puhul arvestatakse nii teaduse olemust (loodusteaduste olemusest arusaamist) kui ka teadmistel põhinevat tehnoloogilist aspekti, mis soodustab õpilaste mõtestatumat käitumist loodusõnnetuste korral.
4. Töötada välja õpetajate koolituskava põhimõtted, mis võimaldavad õpetajal orienteeruda loodusõnnetuste ja NDR-iga seotud õpetamisele, lähtudes väljatöötatud mudelist. Eesmärk on kujundada õpetaja arusaamu ja arvamusi ning tõhustada seeläbi asjakohase hariduskeskkonna kaudu õpilaste vastutustundlikku käitumist loodusõnnetuste korral.

Loodusõnnetuste mõju leevendamise ja hariduspotentsiaali uuringud

Maailma riskiaruande ja selle ühe nurgakivi ehk maailma riskiindeksi (WRI) alusel töötati välja API indeks. Viimane võimaldab riike kogu maailmas võrrelda ning keskendub füüsikaliste ohtude vastastikmõjule ja mõjutatavate elementide tundlikkusele, lähtudes arusaamast, et ekstreemse loodusliku sündmuse intensiivsus pole katastroofiohu hindamisel ainus oluline tegur. Üksnes WRI-st siiski ei piisa, kuna selle alakomponentide seoseid ei ole põhjalikult analüüsitud.

Võttes arvesse nii hariduse tähtsust kui ka valitsuse asjakohaseid meetmeid, esitatakse käesolevas töös indeks, mis lähtub ühelt poolt loodusõnnetuste reaalsest sagedusest piirkonnas ning teiselt poolt riigi teadlikkusest loodusõnnetustest ja valmisolekust mõju leevendamiseks. WRI alakomponentide seoste analüüsi alusel on loodud WRI-st üldisem parameeter, mis näitab loodusõnnetuste reaalse ohu ja valitsuse võetavate meetmete taseme vahekorda ehk riigi haavatavust loodusõnnetuste suhtes. Selle võrdlus riigi haridustaset väljendava PISA testi tulemustega (nn haridustegur) näitab, mil määral haridustase mõjutab riigi haavatavust loodusõnnetuste suhtes. 30 riigi kohta tehtud analüüs osutab hariduspotentsiaalile vähendada loodusõnnetuste korral inimkaotusi.

Loodushariduse edendamine eesmärgiga soodustada vastutustundlikku käitumist ja tõhustada loodusõnnetusteks valmisolekut

Hariduse roll NDR-is sõltub hariduse fookusest ja rõhuasetusest. Vastutustundliku käitumisega seotud tegevuste õpetamisele ja propageerimisele lisaks tuleb haridusmudelis välja pakkuda asjakohane tegevuskava. Sellise loodusteadusliku haridusega seotud mudeli puhul võib eeldada, et see tugineb hariduse omandamise taksonoomiatele ja teooriatele, kuid hõlmab ka mõtestatud õppimist ja pädevusi. Õpetajatele suunatud mudelipõhiste juhiste selgitamiseks on vajalik ka reaalne näitlikustamine ning keskendumine õpetamis- ja õppimisviisile.

Väljatöötatud mudel põhineb teaduskirjanduses esitatud kolmel etapil, millest esimene on motiveeritud õpetamine. Edasiste etappide keskmes on mõistliku kontseptualiseerimise arendamine ja argumenteerimisoskuse edendamine. Doktoritöös esitatud mudelisse on lisatud ka neljas etapp, mis kätkeb sotsiaalteaduslikku arutlusoskust vastutustundliku käitumise arendamisel. Mudeli rakendamisel on tarvis pöörata tähelepanu loodusliku ohuga seotud hoiakutele ja veendumustele ning teaduse ja tehnoloogia olemuse järkjärgulisele kontseptualiseerimisele.

Mudeli väljatöötamise üks eesmärke oli luua lahendus, mis võimaldab tõhusamalt õppida ja õpetada, kuidas leevendada loodusõnnetuste mõju. Selleks koostati uudne õpilaste testimise vahend, mille teoreetilisteks alusteks olid teaduse olemuse kontseptualiseerimine ning sellega seonduva teaduse ja tehnoloogia olemuse määramine, samuti mitmete dispositsioonide ja valdkondadevaheliste oskuste (st 21. sajandi oskuste) arendamine. Keskenduti ka võimalustele ära tunda vastutustundlikku käitumist või tuvastada selle esitamise võimet. Lisaks hõlmas test Eesti, USA ja Jaapani õpilaste kogemusi loodusõnnetustega ning nende riskitaju.

Test, mis põhineb suures osas eespool kirjeldatud mudelil ja on välja töötatud loodushariduse valdkonnas, on suunatud loodusõnnetuste tundmisele ning nende mõju leevendamise õpetamisele ja õppimisele. Testi puhul on uudne see, et õpilased võivad valida ühe neljast kontekstuaalsest stsenaariumist, sidudes aineõppe eetiliste, moraalsete ja muude dilemmadega ning isikliku hariduspädevuse arendamisega. Seeläbi demonstreerivad nad kognitiivseid hoiakuid, mis on vajalikud juhendamaks tegevust õppivaid inimesi. Selline lähenemine erineb USA-s väljatöötatud pragmaatilisest lähenemisest, mis põhineb käitumusliku tegevusega seotud standarditel. Loodusõnnetuste sagenemine ja ulatuse suurenemine tingivad vajaduse arendada õppimisega seotud teadmisi ja oskusi, et võtta loodusõnnetuse korral vastutustundlikke meetmeid.

Indeksi ja mudeli olulisus

Loodusõnnetustest teadlikkuse ja nendeks valmisoleku indeks (API), mis töötati doktoritöö raames välja, ei iseloomusta loodusõnnetuste võimalike riskiallikate erinevusi riigi sees. Seetõttu on selle representatiivsus suurem väiksemates riikides, näiteks Eestis, kus elanike kokkupuude loodusõnnetustega on suhteliselt ühetaoline ja vähetõenäoline. Siiski on API sobiv ja usaldusväärne vahend, mis võimaldab illustreerida teadlikkuse ja valmisoleku suhet valitud Aasia, Euroopa ja Ameerika riikides. Lisaks iseloomustab see indeks riskide vältimist teadlikkuse ja valmisoleku alusel, olles selgemini seotud loodusõpetuse õpetamise ning reaalses maailmas saadud kogemuste ja õpilaste jaoks oluliste igapäevaste kontekstide kaudu.

API järgi olid looduslike ohutegurite ja haridusteguri väärtused omavahel seotud. Samuti ilmnes tugev negatiivne korrelatsioon haridusteguri ning WRI teguritest a) haavatavuse ja b) loodusõnnetustele vastuvõtlikkuse vahel, positiivne korrelatsioon aga c) toimetulekuvõime, d) kohanemisvõime ning e) toimetuleku- ja kohanemisvõime kombinatsiooni vahel. 30 riigi andmetele tuginedes oli toimetuleku- ja kohanemisvõime kombinatsiooni korral API väärtus vahemikus 103–320, mis näitab, et Eesti ja USA näitajad olid üsna sarnaselt kõrged, kuid jäid ala Jaapani omadele. See viitab, et Jaapan on looduslike ohtude käsitlemisel suhteliselt teadlikum ja sealne valmisolek ohtudega tegelda on suurem. Kõik see kinnitab hariduse olulisust loodusõnnetuste tagajärgede ennetamisel ja leevendamisel.

Õpetamise rõhuasetuste sobivus ja tähtsus loodusõnnetuste mõju leevendamisel

Teoreetilisest vaatenurgast (joonis 1) ja õpetamise suunitluse alusel (joonis 2) väljatöötatud mudel hõlmab NDR-i jaoks üldiselt sobivat õppeedastust. Õppimise edenemine põhineb teaduse ja tehnoloogia olemuse mõtestatud kasutamisel ning õpilaste hoiakute järkjärgulisel hindamisel ning juhib õppimist vastutustundliku käitumise suunas. Esialgse kolmeetapilise režiimi asemel on neljaetapiline õpetamis- ja/või õppimisrežiim. Intervjueeritud õpetajad tajusid, et joonisel 2 esitatud õpetamise rõhutamise skeem oli sobiv. Samas nad soovitasid, et kuigi joonisel 1 esitatud õpetamisviisiks on vaja rohkem aega, tuleks NDR-i õpetamisele ja õppimisele suuremat rõhku panna. Siit nähtub, et õpetajad peavad NDR-i õpetamist ja õppimist tähtsaks.

Enamik õpetajaid näis nõustuvat, et oluline on õpilastele õpetada, kuidas rakendada vastutustundliku käitumisega seotud tegevusi ka kujuteldava NDR-olukorra korral. See näitab, et sisuliste tegevuste õpetamiseks/õppimiseks võib lisada kolmeetapilisele mudelile (kontseptualiseerimine, dekontekstualiseerimine, uuesti kontekstualiseerimine) käitumusliku tegevuse etapi, millega kaasneb lisavastutus.

Intervjuu vastused näisid tugevdavat õpetajate usku, et õpetamisprotsessis on suurem rõhk NDR-il. Seda tõendavad positiivsed vastused, mis on esitatud õpetaja küsimustiku vastavates punktides.

Küsimustikule antud vastuste ja jätkuintervjuude alusel võib öelda, et õpetajate arvates on väärtuslik, kui õpilased saavad õppida, kuidas väljamõeldud loodusõnnetuse korral tegutseda vastutustundlikult viisil, mis vähendab riske ja päästab elusid. Joonistel 1 ja 2 esitatud õppimise edenemine tunnistati potentsiaalselt tõhusaks raamistikuks.

PUBLICATIONS

CURRICULUM VITAE

Name: David Cerulli
Date of Birth: 08.27.1984
Nationality: United States
Address: University of Tartu, Vanemuise 46, Tartu, 51014
E-mail: dc10739@gmail.com

Education:

2011	M.Ed, Earth Science Education 7–12, Hunter College, New York, New York
2007	M.A, Human Geography, Macquarie University, Sydney, New South Wales
2006	B.S. Geography, Salisbury University, Salisbury, Maryland

Work History:

09/2020 – …...	High School Integrated Science Teacher
09/2019 – 09/2020	Middle School Living Environment and Earth Science Teacher
09/2017 – 09/2018	Earth Science Teacher
10/2014 – 06/2016	Science and Social Studies Teacher
2/2014 – 5/2014	Human Geography Instructor, History Department
2/2012 – 5/2014	Geology Instructor, Chemistry Department
6/2006 – 6/2014	High School Earth Science and Chemistry Teacher
1/2008 – 1/2009	English as a second language teacher

Profession:

High School Teacher

Publications:

Cerulli, D. Scott, M. Aunap, R. Kull, A. Pärn, J. Holbrook, J. Mander, Ü. (2020). The Role of Education in Increasing Awareness and Reducing Impact of Natural Hazards. *Sustainability,* 12, 7623. https://doi.org/10.3390/su12187623

Cerulli, D., Holbrook, J., Mander, U. (2016). Devising an instrument for determining students' preparedness for an Education through Science learning approach within the topic of Natural Hazards. *Science Education International, 27*(1), 59–87. EJ1100160

Cerulli, D., Holbrook, J. (2019). Exploring The Effect of NOS/NOT Learning and Dispositions on Undertaking Behavioural Actions In the Case of Natural Hazards. *Journal of Baltic Science Education*, *18*(4), 519–536. https://doi.org/10.33225/jbse/19.18.519

ELULOOKIRJELDUS

Nimi:	David Cerulli
Sünniaeg:	08.27.1984
Kodakondsus:	United States
Aadress:	University of Tartu, Vanemuise 46, Tartu, 51014
E-mail:	dc10739@gmail.com

Haridustee:

2011	M.Ed, Earth Science Education 7–12, Hunter College, New York, New York
2007	M.A, Human Geography, Macquarie University, Sydney, New South Wales
2006	B.S. Geography, Salisbury University, Salisbury, Maryland

Teenistuskäik:

09/2020 – …...	High School Integrated Science Teacher
09/2019 – 09/2020	Middle School Living Environment and Earth Science Teacher
09/2017 – 09/2018	Earth Science Teacher
10/2014 – 06/2016	Science and Social Studies Teacher
2/2014 – 5/2014	Human Geography Instructor, History Department
2/2012 – 5/2014	Geology Instructor, Chemistry Department
6/2006 – 6/2014	High School Earth Science and Chemistry Teacher
1/2008 – 1/2009	English as a second language teacher

Teadustegevus:

Gümnaasiumi õpetaja

Publikatsioonid:

Cerulli, D. Scott, M. Aunap, R. Kull, A. Pärn, J. Holbrook, J. Mander, Ü. (2020). The Role of Education in Increasing Awareness and Reducing Impact of Natural Hazards. *Sustainability,* 12, 7623. https://doi.org/10.3390/su12187623

Cerulli, D., Holbrook, J., Mander, U. (2016). Devising an instrument for determining students' preparedness for an Education through Science learning approach within the topic of Natural Hazards. *Science Education International, 27*(1), 59–87. EJ1100160

Cerulli, D., Holbrook, J. (2019). Exploring The Effect of NOS/NOT Learning and Dispositions on Undertaking Behavioural Actions In the Case of Natural Hazards. *Journal of Baltic Science Education*, *18*(4), 519–536. https://doi.org/10.33225/jbse/19.18.519

DISSERTATIONES PEDAGOGICAE SCIENTIARUM UNIVERSITATIS TARTUENSIS

1. **Miia Rannikmäe**. Operationalisation of Scientific and Technological Literacy in the Teaching of Science. Tartu, 2001.
2. **Margus Pedaste**. Problem solving in web-based learning environment. Tartu, 2006.
3. **Klaara Kask**. A study of science teacher development towards open inquiry teaching through an intervention programme. Tartu, 2009.
4. **Anne Laius**. A longitudinal study of science teacher change and its impact on student change in scientific creativity and socio-scientific reasoning skills. Tartu, 2011.
5. **Katrin Vaino**. A case study approach to effect change of chemistry teacher beliefs for enhancing students' scientific literacy. Tartu, 2013, 176 p.
6. **Mario Mäeots**. Inquiry-based learning in a web-based learning environment: a theoretical framework of inquiry-based learning processes. Tartu, 2014, 126 p.
7. **Regina Soobard**. A study of gymnasium students' scientific literacy development based on determinants of cognitive learning outcomes and self-perception. Tartu, 2015, 142 p.
8. **Ana Valdmann**. Determining categories of self – efficacy and levels of teacher ownership following promotion of science teacher's operational needs. Tartu, 2018, 219 p.
9. **Tormi Kotkas**. Designing, Implementing and Evaluating Teaching and Learning Modules for Promoting Decision-making Towards STEM Careers. Tartu, 2021, 202 p.