Devising an instrument for determining students' preparedness for an Education through Science learning approach within the topic of Natural Hazards

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ABSTRACT: As global average temperatures rise, there has been an increase in the frequency and magnitude of meteorological natural hazards. To survive in the world and thrive in the work place, students need to utilize educational skills (such as creative thinking, non-routine problem solving, collaboration and systems thinking) and become independent thinkers. Such learning can be encompassed under the heading of education through science. This study strives to develop a research instrument, which meaningfully determines student preparedness for dealing with natural hazards, based on their education through science learning, including student understanding of the Nature of Science (NOS) and Nature of Technology (NOT). The instrument, piloted with students in grades 7th/8th and 10th/11th in North America and Europe, is designed to allow comparisons across cultures. Outcomes show that the devised instrument is suitable for determining student competences and understanding of NOS/NOT associated with values and attitudes for students from different cultural backgrounds, and determining awareness of natural hazards and the use of appropriate behavioural actions related to disaster risk reduction for students from different cultural backgrounds.

KEY WORDS: Nature of science (NOS); Natural hazards; Natural hazard responses; Education through science (EtS); Nature of technology (NOT).

INTRODUCTION

As human activity supported by new technology has increased, anthropogenic factors have increased the average global temperature of the Earth (Dean, 2015; Spencer, 2007). This has resulted in higher occurrence of severe weather conditions e.g. thunderstorms (lightning), hurricanes/typhoons/ cyclones (Holland & Bruyere, 2014), tornadoes, etc. (Collins & An, 2010; Phillips & Schmidlin, 2013).

This has suggested that in education, students need to be subjected to the crucial responsibilities of reacting to a natural hazard in a way that minimizes risk and loss of life i.e. undertake behavioural actions, especially

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in connection with disaster risk reduction linked to responsible citizenship (Oyao, Holbrook, Rannikmae & Pagusan, 2015). However, in the US, within the Next Generation Science Standards (NGSS, 2013) and the New York State Earth Science curriculum (NYS Ed. Dept, 2000), as well as in Europe e.g. Estonian National curriculum (Estonian Government, 2011), there is no mention of natural hazard responses. Nevertheless, there is some mention of risk reduction in the Next Generation Science Standings (NGSS), the first set of National (USA) science standards set to be adopted by 17 states and the District of Colombia as of November 2015 (http://academicbenchmarks.com/next-generation-science-standards-adoption-map/).

Due to varying exposure to natural hazard risk between nations, natural hazards affect countries disproportionately and in different ways. Furthermore, natural hazards are addressed by people, based on their embedded cultural attributes. This can lead to different interactions, especially taking into consideration that science is a human enterprise practiced in different ways within cultural settings (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). It suggests that scientific orientations can vary from region to region and nation to nation due to varying cultural perceptions. But with easy and affordable travel worldwide and the interest to explore other countries and climatic conditions, people from different countries are exposed to natural hazards, not necessarily met in their own country. For example, on December 26, 2004, a magnitude 9.15 earthquake, recorded off the coast of Sumatra, Indonesia (Chlieh et al., 2007), is recognised as triggering a tsunami that left over 231,000 people dead, primarily in Indonesia, India, Thailand, and Sri Lanka (Stone, 2005), including foreigners from 44 countries (James, 2005). The event stimulated worldwide recognition that greater awareness of such natural hazards and actions is needed to reduce risks of casualties and fatalities before, during and after a hazard occurs. This, in turn, suggests a more holistic education (which includes risk-reduction) related to the causes and effects of natural hazards and how people can respond, is needed. Also related to this is the need to be aware of technological developments which can impact on such situations, thus appreciating that technology may have the potential to alleviate or greatly reduce casualties and fatalities in the event of a natural hazard, especially through enhanced detection and communication. Unfortunately, existing geography, or earth science education, mostly focuses on knowledge acquisition of hazards (Tytler, 2007) and not human perception of hazards. The current tendency in most curricula around the world is to focus on natural hazard content knowledge (e.g. NYS Ed. Dept., 2000; Estonian Government, 2011). For example, the emphasis is on the science behind 'why a tsunami occurs,' whereas a much wider educational approach, encompassing actions in the face of natural hazards and risk

reduction, is seen as important, in addition to the learning of the conceptual science behind natural hazards.

With an increasing frequency in the occurrence of natural hazards and the likelihood of this increasing still further in the future, it seems important that students be educated to deal with new situations. In this, scientific thinking and human values can play a useful role and enable greater appreciation of new technologies, which are predicted to be available in the future. This, in turn, can enable students, as future adults, to not only be aware of advances on the scientific front, but also developments in the field of technology, plus opportunities to develop wider values, attitudes, skills and knowledge (VASKs), which may play an important role with respect to hazard responses. Arguably, there is a need for a change in the way education within science classes (i.e. education through science lessons) is taught in schools. Thus, for example, education can promote a holistic approach to teaching natural hazards – both meteorological and tectonic.

Within this holistic approach, an appreciation of the Nature of Science (NOS) and the Nature of Technology (NOT) are vital, as students need to understand the meaning of science and technology and their capabilities. Natural hazards education provides a context for teaching NOS/NOT implicitly, as it relates to the science behind natural hazards taking into account cultural embeddedness. This involves considerations of social and cultural elements, such as economics, religious beliefs, philosophy and politics and their impact on how scientific knowledge and technology are viewed.

While prior research concerns the rebuilding / relocating of communities (Kim, Woosnam & Aleshinloye, 2014; Loucks, Stedinger & Stakhiv, 2006) and research has similarly been conducted concerning the vulnerability of cities and regions to natural hazards (Collins & An, 2010; Santos, Tavares, & Emidio, 2014), far less research has been undertaken concerning individual and group responses to natural hazards, particularly on cross-cultural comparisons. The purpose of this research is to determine students' understanding about natural hazards, both familiar and unfamiliar, so as to probe cultural differences in student current learning related to natural hazard responses.

The goal of this study is to develop a valid instrument to determine students' preparedness, with respect to educational expectations related to natural hazard responses in at least two continents (Europe and North America). The hypothesis put forward is that students should receive more exposure to being taught about natural hazards and ways to respond to reduce the risk, irrespective of whether all such natural hazards occur in their country or not. The associated research questions are put forward as:

1. How valid is an instrument created for determining student competences (VASKs) and understanding of NOS/NOT, associated with (personal/socio-cultural) values and attitudes, for

students from different cultural backgrounds when posed in a natural hazard context?

2. How valid is the instrument in determining awareness of natural hazards and the use of appropriate behavioural actions, related to disaster risk reduction, for students from different cultural backgrounds?

LITERATURE REVIEW

Natural Hazards

While significant research exists regarding post-natural hazard responses (Kim, Woosam & Aleshinloye, 2014; Loucks, Stedinger & Stakhiv, 2006; Collins & An, 2010; Santos, Tavares, & Emidio, 2014), there appears to be a dearth of studies related to natural hazard responses while they're occurring. Thus far, research has focused heavily on knowledge acquisition. For example, a recent study indicates that 'current lightning safety research lacks a focus on lightning safety education, the status of education, while the modes for best education practices are not widely studied' (Phillips & Schmidlin, 2013, pp. 1232). In this study, university students from the United States, tested on lightning safety knowledge in three lightning-prone states in a pre/post survey study, indicate that past lightning death rates are not correlated with lightning safety knowledge. The results of the study by Phillips & Schmidlin suggest that research on natural hazard safety knowledge needs to be taken a step further, from 20th century education perspective to that more appropriate for the 21st century. It is suggested there is a need for a wider perspective, which encompasses values and attitudes. By developing wider values and attitudes, teaching and learning in science connects with relevant societal contexts, increasing student interest (Tytler, 2007), while helping students decide what to do with scientific knowledge gained.

The literature indicates there is a lack of action during natural hazard responses, especially if it is from a second-hand experience. Studies by Kunreuther (1978); Peek and Mileti (2002); Siegrist and Gutscher (2008), as cited in Harvatt, Petts and Chilvers (2010), indicate that there is substantial evidence that householders residing in natural hazard prone areas fail to act or do little to reduce risks of property damage, casualties or fatalities. Whitmarsh, 2008 states 'that second-hand experience (i.e. information) about flood risk is less likely to produce action than direct knowledge and social interaction' (pp. 65). This suggests that without experiencing the natural hazard on a first hand basis, it is difficult to respond to this natural hazard in a way that reduces risk. However, it contrasts with the conclusions from a Phillips and Schmidlin (2013) study, which indicate that there is not a positive correlation between experience with lightning

and lightning safety knowledge. The meaning of experience in this context, however, may be open to interpretation.

A study in 2011 assessed the level of lightning safety awareness in three parks in the Sierra Nevada Mountains in California, United States. Survey results from this study show that lightning safety awareness was greater from participants responding in natural parks than those in an urban setting (Weichenthal et al., 2011). This points to urban dwellers being less prepared to respond to lightning strikes and that more research needs to be undertaken to investigate the sources of this educational disparity.

Dogulu et al., 2014 examined tsunami resilient communities and found that such communities were relatively well covered in terms of technical components, such as tsunami warning/ information centres (http://ptwc.weather.gov) and evacuation planning/mapping (Gonzalez-Riancho et al., 2014; Dall'Osso & Dominey-Howes, 2010). However, far less research had been undertaken in social science aspects related to tsunami resilience (Dogulu et al., 2014). Further, Dogulu et al., found that research efforts had focused mainly on SE Asia and the Pacific, with research studies in Europe being comparatively lacking.

Education through science (EtS)

In a science education environment, where students 'learn fundamental science knowledge, concepts, theories and laws,' the approach can be described as 'science through education.' The problem with the science through education approach is that it is not very interesting for many students and focuses on building a base of knowledge for future scientists (Holbrook, 2013). An alternative, 'education through science' approach, however, places emphasis on educational gains, with students learning science knowledge, concepts and values which are not only important for understanding but goes further into developing, for example, the capability for suitably handling socio-scientific issues within society (Holbrook & Rannikmae, 2007). By putting emphasis on educational considerations associated with decision making, as well as problem solving, the educational focus seeks stronger attention to developing capabilities to act. Furthermore, by adopting an educational approach, such as initiating school science learning by presenting students with a real world context, can be expected to make lessons more relevant for students (Holbrook & Rannikmae, 2010; Gilbert, Pilot & Bulte, 2011). The 'education through science' approach moves the teaching of school science away from gaining isolated content and can be taken as an umbrella term for promoting learning beyond abilities toward developing capabilities in unknown situations (Oyao, Holbrook, Rannikmae & Pagusan, 2015), guiding students towards self-determination (Ryan & Deci, 2000) and meta-cognition. Reasoned socio-scientific decision making (Choi et al., 2011), plus encompassing skills such as creativity, communication, collaboration

(Partnership for 21st century skills, 2011) represent an education through science approach.

Nature of Science (NOS) and Nature of Technology (NOT)

Research indicates that most students do not adequately understand NOS and NOT. For example, Lederman (2007, pp381) points out: "high school graduates, and the general citizenry do not possess (and never have possessed) adequate views of NOS." Current methods of teaching NOS have largely been ineffective (Erduran, 2014; Bayir, Cakici, & Ertas, 2013). Previous attempts to increase student understanding related to NOS have failed (Lederman, 1992; 2007). Learning NOS as a list of facts does not give significant benefit to students; inquiry and problem-based assignments have a much more positive effect on interest, motivation and attitude in students (Potvin & Hasni, 2014). This suggests the convergent aspects of NOS should be taught implicitly through the context of science, such as natural hazards. Parts B & C of the questionnaire devised for this research assess competences related to NOS. This is important because it forms the foundation for learning in all areas of science.

NOT is a more difficult term to define than NOS and it seems no clear-cut meaning exists. For the most part, it's clearly associated with NOS, as the ideas behind the technology have a scientific conceptualization (Constantinou, Hadjilouca & Paradouris, 2010). However, there is ample evidence to suggest that technological developments can occur with an understanding of the science, or the limitations of science. In fact, much technology may arise from creative thinking and the ability to adapt to new situations and hence an understanding of technology may well lend itself to education through science attributes associated with creating and critical thinking and development skills. It seems there is a need to seek ways to integrate the learning of NOS/NOT within the teaching of scientific concepts (Peters, 2009). Though no consensus definition for NOT exists, DiGironimo (2011) has developed a framework for measuring student conceptions of NOT based on five convergent aspects of NOT knowledge: technology as artefacts; technology as a creation process; technology as a human practice; history of technology; the current role of technology in society. The history of technology is shown at the base and the current role of technology in society is shown at the top of a prism, with technology as artefacts, technology as a creation process and technology as a human practice on each side. This framework provides a foundation for future research on student conceptions of NOT.

Technological advances can be applied to tsunami warning systems, reducing risks. For example, following the December 26th, 2004 tsunami in the Indian Ocean, tsunami early warning systems have been put in place (Løvholt et. al., 2014), demonstrating the application of technology. However, much work has yet to be done: on the March 11th, 2011 the

Tohoku tsunami in Japan caused a nuclear disaster. Another example is the tsunami which hit the Mentawai islands of Indonesia on October 24th, 2010 (Løvholt et. al., 2014). Both of these disasters occurred in areas where preventative tsunami risk reduction measures were already in place. This demonstrates the need for improved technological measures.

A Framework for Learning Natural Hazards within an Education through Science context

Based on the literature, a framework can be constructed that interrelates the various aspects associated with competences, education through science and NOS/NOT. Such a framework (figure 1) provides a guide for 'education through science' lesson progression through teaching natural hazards. The learning progression is based on a holistic approach, where all forms of natural hazards are taught but the learning progresses from the lower level (V), as student abilities and capabilities develop to the higher (S) level. The learning progression gradually encompasses different stages of a three-stage model (V, U, T) (Holbrook & Rannikmae, 2010).
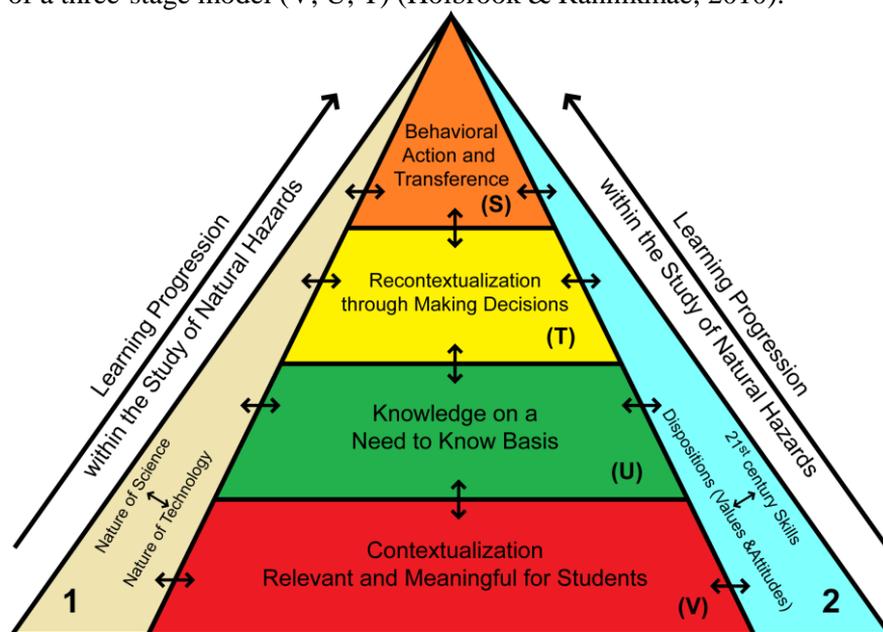
Figure 1   **A hierarchical framework based on 'education through science,' emphasizing a 3-stage approach to learning through natural hazards**

Initially, the model is a strategy for teaching, aiming to make lessons more relevant to students' everyday lives. However later learning progressively moves towards an emphasis on responsible behavioural

action (level S) (Oyao, Holbrook, Rannikmae & Pagunsan, 2015). In this, responsible behavioural action refers to behaviour based on capabilities in the wake of a natural hazard episode.Throughout the learning progression, NOS/NOT and their inter-relationship are taught implicitly through the contextual medium of natural hazards. Similarly, throughout the learning progression, students gain and utilize skills to better prepare them for 21st century (Pellegrino, 2012) competences.

Values and attitudes are shown as interacting with all components of the framework. As values and attitudes vary between individuals and across cultures, values and attitudes will also influence decision making during the event of a natural hazard.

At the base is contextualization, taken to mean in this model, realizing Geography/Earth Science as something students are considered likely to have experienced or made aware of. Thus contextualization seeks to make the learning more relevant and meaningful for students (Holbrook & Rannikmae, 2010) through the context. A context-based approach allows the educator to engage students by providing real world relevance and draw upon students' pre-knowledge. This serves as a base to induce student intrinsic motivation in the subject (Ryan & Deci, 2000). Decontextualisation refers to de-escalating from teaching through context to teaching through content. Improvements in technology have led to an increasing amount of knowledge, and easier access to it (Tytler, 2007). With this overwhelming amount of knowledge available, teaching on a need to know basis becomes necessary and allows students to focus on the knowledge they can apply to the initial context. At this level [U], no contextualization occurs because students need to focus on acquiring knowledge about the science behind natural hazards. After students have acquired the necessary competences, re-contextualisation [T] allows students to apply not only their knowledge and skills, but also the values and attitudes that affect behavioural action (Oyao, Holbrook, Rannikmae & Pagusan, 2015).

When students have developed a capability to transfer learning of responsible behavioural action from one type of hazard to another, this important skill can be termed transference. It is attained through student progression, because the acquired capability comes from developing students' informed decisions making and associated behavioural actions across multiple contexts.

METHODOLOGY

This study seeks to develop a validated instrument, based on the prepared framework, to determine students' learning related to natural hazards and disaster risk reduction across cultural settings associated with the various levels within the framework.

Sample

To check the initial suitability of the instrument, 135 (grades 7th/8th & 10th/11th) geography students from four secondary schools in Estonia and 55 geography students from grades 7th/8th in Maryland, United States were tested using the draft instrument. The students were selected based on convenience and completed the pencil and paper test in their classrooms during one lesson period.

Instrument Design

The initial instrument was created with two main sections: section 1 related to framework levels V, U, T (see figure 1) linked to conceptualizations of natural hazards and NOS/NOT, while section 2 at level S (figure 1), was associated with behavioural actions.

Section 1 of the instrument. This is subdivided into four parts, labelled A-D. Part A enables the collection of background information from students such as gender, grade level and which natural hazards the students have experienced. This allows data analysis findings based on stratification by gender, grade level, and level of natural hazard experience. In part B, the questions seek students' agreement with a number of statements on natural hazards and NOS/NOT using a five point Likert scale (1-5) -- strongly disagree; disagree; neutral; agree and strongly agree. Students also explain their responses. This part is important, because it can measure student NOS/NOT knowledge associated with natural hazards and indicate which aspects of NOS/NOT are the most poorly understood with a view to improve understanding in the future. Although part B consists of 14 separate questions, any one student completes 10 questions where four questions are required to explain their responses. This is because:

   a. time limitations: students are not expected to have time to complete all 14 questions for part B and give an explanation for each;
   b. necessity: students explain their response which are relevant to the specific scenario answered in part E.

In part C, students' respond to a single open-ended question probing their understanding of the relationship between science and technology. This is included to determine students' understanding of the inter-relationship between science and technology, indicated in research studies as poor (Constantinou, Hadjilouca & Papadouris, 2010).

In Part D, students again respond to a single question. Students' rank meteorological and tectonic natural hazards from the least to the most dangerous, based on their opinions to indicate perceived risk. Their opinions are expected to provide an understanding of the difference between natural hazard awareness across cultures.

Section 2 of the instrument. Part E is based on an outset map of a fictitious island, which suffers from a large variety of natural hazards. This situation allows a number of different natural hazard scenarios to be created, as well as complex responses to be solicited from students to determine ability in identifying appropriate behavioural actions. Part E consists of 4 questions, but an individual student answers only one of these. Separate inset maps, giving a more detailed view, are provided for each natural hazard scenario (except lightning strikes) and thus each student receives only one of these. The purpose of the inset maps is to provide more explicit detail, allowing students to more easily respond to the questions given.

A description of each of the 4 scenarios and the skills required are given in Appendix 1.

The validity of the instrument was determined in two major ways. First, by seeking feedback from a presentation made to education researchers plus interviews with a senior geography academic and, separately, with a group of geography educators/teachers. Second, by collecting and analysing piloting data from two countries – Estonia and the USA.

Based on the above, examples of modifications made to the Earthquake scenario were:

1. removal of text where students were asked unnecessarily 'how would you respond' more than once.
2. the task was modified to make it explicit that the frequency and magnitude of the earthquake were not known at the time the hazard occurred;
3. addition information was provided to indicate that the building was made from concrete and was a high quality construction;
4. the plate boundary map was changed to include the underlying plate structure.

Piloting

Following the adjustments made from piloting in Estonia, another round of piloting was conducted on the East Coast of United States. These two countries were selected because they are presently the only countries in the cross cultural comparison (more TBD). The first stage of piloting was done to refine the presentation of the test while the other was to compare cultural validity.

Data collection

Data collection was carried out in Estonia and the East Coast of the United States in the 2015-2016 school year. Written data and data on the maps was collected using pencil and paper. Colour prints of the outset map were used.

In trying out the instrument, each student received both a set of questions in 5 sections (A-E) 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 teachers - Read the directions aloud to students for all parts A-E. Remind students to draw their route on the outset map. Ask if there are any questions before they begin. Help students who are struggling with directions.

Data analysis

Data was analysed utilizing MS Excel software. Averages were computed based on the total number of responses. Bar graphs were generated based on percentage responses.
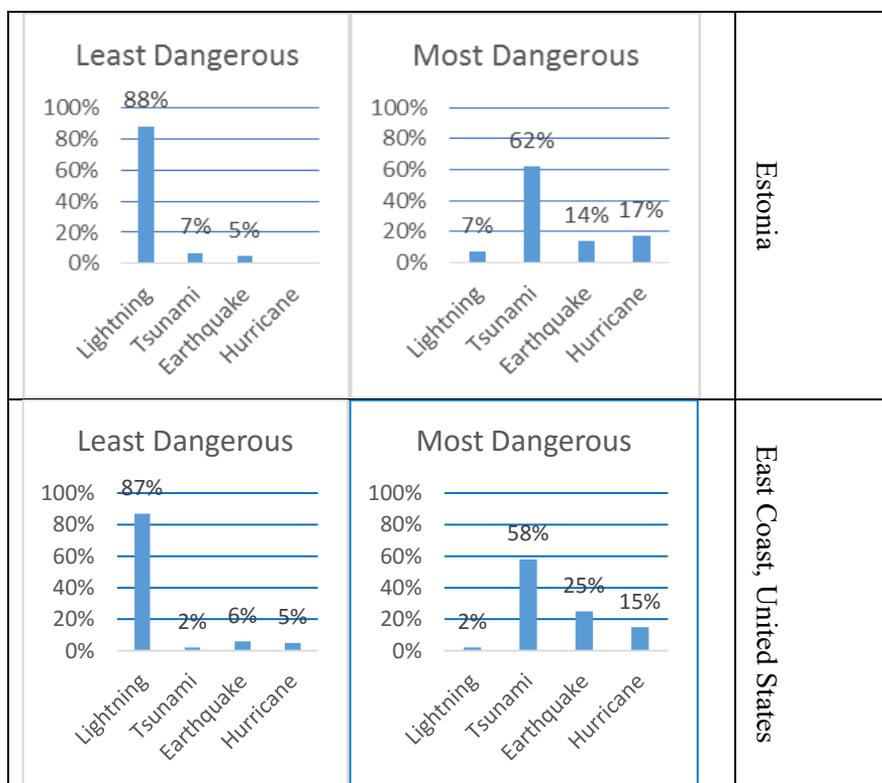
Figure 2   Part D - Perceived risk of natural hazards

RESULTS

Student responses from piloting in Estonia and the USA are shown in Appendix 2 in graphical formats.

Additionally, all students responded to the question related to the perceived risk of natural hazards. Figure 2 clearly shows that lightning was recognized as the least dangerous natural hazard and tsunamis as the most dangerous. The largest discrepancy between the Estonia and US responses were related to earthquakes.

Moreover, students were asked to rate natural hazards, based on which they think are the most and least dangerous, irrespective of their geographical location. The number of students who rating each hazard as the most and least dangerous were tallied up and then displayed in percentages in the graphs shown in figure 3-a.

Students were asked to rate each hazard on a relative scale from most to least dangerous. The figure 3-b shows the percentages of students indicating the hazards they perceive to be the most and least dangerous, based on different hazards they had experienced.
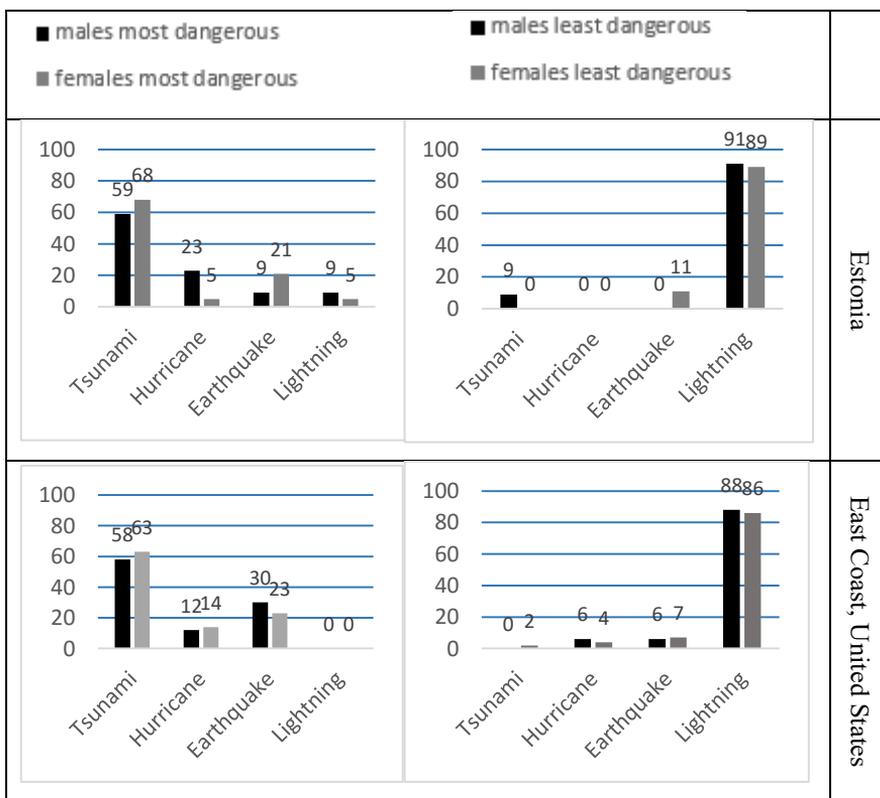

Figure 3-a   Perceived hazard severity rankings by gender

Figure 3-b   Perceived hazard severity rankings by experience

Students were asked to rate each hazard on a relative scale from most to least dangerous. The figure 3-b shows the percentages of students indicating the hazards they perceive to be the most and least dangerous, based on different hazards they had experienced.
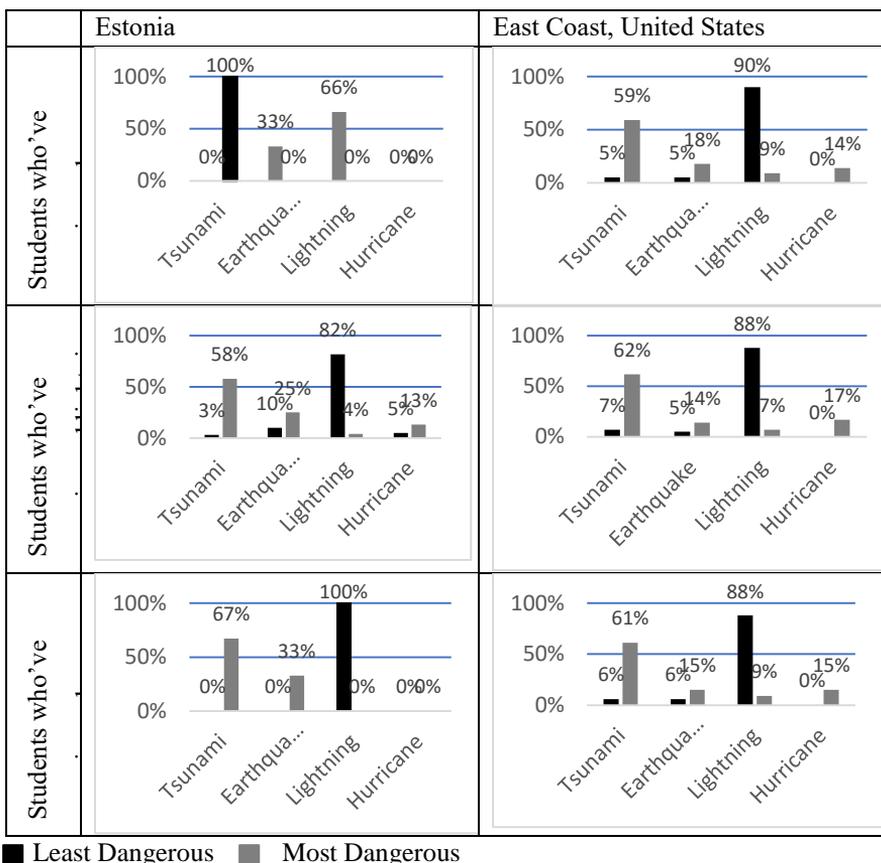
Section 2. The graphs below (figure 4) show the percentage response from those students who answered the scenario indicated. Student responses were classified as either responsible or irresponsible depending on the actions indicated for the four scenarios in part E- Behavioural Action.

Criteria for student responses exhibiting responsible behavioural action include risk reduction in line with natural hazard safety knowledge. Exemplary responses include elements of creativity and communication in a way that helps others by reducing their chances of casualties or fatalities. Characteristics of irresponsible behavioural action include risky responses, especially those that confound natural hazard safety knowledge.
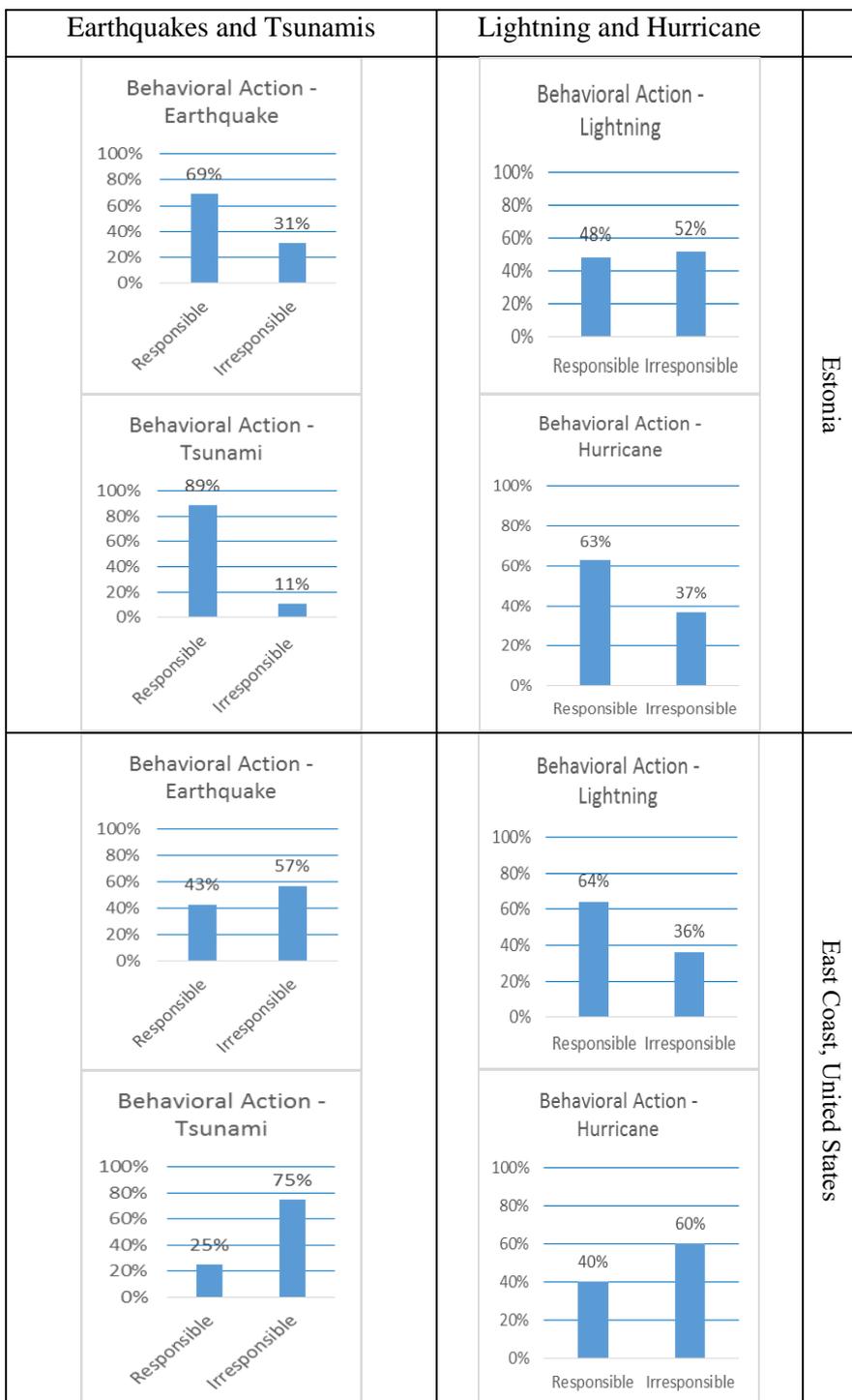
Earthquakes and Tsunamis	Lightning and Hurricane	
Behavioral Action - Earthquake — Responsible 69%, Irresponsible 31%	**Behavioral Action - Lightning** — Responsible 48%, Irresponsible 52%	Estonia
Behavioral Action - Tsunami — Responsible 89%, Irresponsible 11%	**Behavioral Action - Hurricane** — Responsible 63%, Irresponsible 37%	
Behavioral Action - Earthquake — Responsible 43%, Irresponsible 57%	**Behavioral Action - Lightning** — Responsible 64%, Irresponsible 36%	East Coast, United States
Behavioral Action - Tsunami — Responsible 25%, Irresponsible 75%	**Behavioral Action - Hurricane** — Responsible 40%, Irresponsible 60%	

Figure 4   Student responses exhibiting behavioural action

DISCUSSION

In part B, responses between cultures exhibited by students from Estonia and the East Coast of the US contrasted heavily. Large contrasts in responses also exist when sorted by gender and hazard experience. The majority of students for all questions (1-14), with the exception of numbers 12 and 13, contrasted in their agreement or disagreement between the two student groups. For example, for B1, the majority of students from Estonia disagreed, while the majority of students from United States agreed that 'Meteorologists can determine precisely how many Hurricanes will strike in a given area every year by utilizing modern technology and science.' This perhaps highlights cultural differences.

In terms of measuring meaningful understandings of NOS/NOT, students from Estonia responded correctly 4/14 (29%) times while students from the USA responded correctly 11/14 (79%) times. This suggests that students from the USA have a better understanding of NOS/NOT than their Estonian counterparts.

Nevertheless, as the majority of students from either Estonia or US either agreed or disagreed with each statement, with very few students leaving questions unanswered, the appropriateness of part B of the instrument is seen as validated. It is thus seen as useful set of questions for highlighting potential cultures differences related to competences and NOS/NOT conceptualizations through a natural hazard context.

In part C, student responses indicate that students from both Estonia and US understand that science and technology are interrelated. However, the majority of students did not identify the bi-directional relationship that exists between science and technology. As research has shown (Constantinou, Hadjilouca & Papadouris, 2010), students do not adequately understand the inter-relationship between science and technology, and hence this misunderstanding is not surprising. Male students from the USA were generally able to indicate there is a bi-directional relationship between Science and Technology, while USA female students had the largest share of responses indicating science and technology are independent. The question was determined to be appropriate for further use.

For part D, students in both countries responded similarly. In both countries, students indicated that lightning strikes were the least dangerous while tsunamis were the most dangerous. This was somewhat surprising because few or no students indicated that they had experienced a tsunami, while almost every student had indicated that they had experienced lightning strikes. This information is worth including in the questionnaire, because it can inform developments of teacher-learner materials related to natural hazards. Little misunderstanding of the question was detected and hence part D was considered appropriate.

It was surprising to see that students were so aware of the dangers of tsunamis. Perhaps their answers are in response to a greater awareness of tsunamis from the media.

A few mistakes in the text for part E and responses by students were found in the research instrument after piloting in Estonia. These are elaborated below:

1. As all four scenarios utilize the same outset map, previously unforeseen conflicts arose following piloting. For example, the starting point on the outset map in the lightning scenario (point 'L1') was in close proximity to the starting point for the hurricane scenario (point 'H'). In an effort to highlight that students should imagine point 'H' was their home, additional text was seen as necessary on the outset map indicating 'your home.' Students from point 'L1' simply responded by drawing a route on the map from point 'L1' to point 'H', rendering the scenario too simple and confounding the complexity of the intended scenario. Thus an important modification deemed appropriate was to remove the 'your home' label as to avoid this confusion. The instrument was then further piloted on the East Coast of United States, and the issue in this scenario was no longer seen as problematic because confusion between variables of separate natural hazard scenarios was reduced.

2. In the description of each of the four natural hazard scenarios, it was found that the question: 'how would you respond in this scenario' was asked twice. Students were asked how they would respond during the description of the scenario, and then asked again following the scenario description. For example, the pre-piloting hurricane scenario asked: 'You're at your home at location 'H' (E7). You're with your mother, father sister and brother. You see on your mobile phone that a storm is coming and that it's recommended for you to evacuate. Would you evacuate? How would you respond in this scenario? What are the greatest risks for staying or evacuating? After examining conditions on the evacuation routes, draw in a line on the outset map of the route that you'd take. Explain why.' Then, after this initial description, a subset of questions followed: 'Would you evacuate'; 'What are the greatest risks for staying or evacuating'?; 'If evacuating, would you take your car, bike, walk or swim (or other)'?; 'After examining conditions the evacuation routes, draw on the overview (large outset) map of the route that you'd take.' Although it was recognized that students were generally able to respond, adjustments were made accordingly.

During the piloting it was found that the instrument took students more time to complete than was considered reasonable. The responses were that

each student need only respond to one natural hazard scenario. Thus for the purposes of sampling, it was considered appropriate to subdivided the students randomly so that any one student responded to one scenario and also only a sub-section of questions in section B. This contributed to alleviating the concern that the instrument took too long for students to complete, yet permitted wider coverage.

Despite lightning being the most frequently experienced natural hazard in Estonia, behavioural actions were given less responsibly than by students from the East Coast, United States. It seems that there is a complacency of Estonian students towards lightning responses. Where there was perhaps some concern with the question, from a more detailed look at the questions, it seems that the students were having difficulty with the question itself, rather than its wording. Conversely, although most students from Estonia had not experienced a hurricane, their responses were generally more responsible than their counter-parts from the East Coast of United States. Here, most students indicated that they had experienced hurricanes. This may indicate a certain degree of complacency experienced in dealing with frequently experienced natural hazards and draw attention to a need for more focus on behavioural action teaching.

For each of the four scenarios (lightning, earthquake, tsunami, hurricane), the questions were suitably portrayed so that students were able to respond to behavioural actions. This responsibility was most evident in the event of a tsunami and least responsible for lightning strikes. Although only a few students from Estonia were likely to have experienced a tsunami, the majority were capable of responding responsibly in the tsunami scenario. This indicates that the behavioural action within the question was suitably portrayed. In contrast, students showed far less responsible actions in the event of lightning strikes. However, the question is validated by the higher proportion of appropriate responses from the US. The revised version of the instrument was deemed appropriate.

CONCLUSION

Based on the student results and taking into account modifications indicated, the research instrument was deemed suitable for determining student competences and understanding of NOS/NOT, associated with values and attitudes for students from different cultural backgrounds in a natural hazards context.

The research instrument was also deemed suitable for determining awareness of natural hazards and the use of appropriate behavioural actions, related to disaster risk reduction, for students from different cultural backgrounds because there is a majority of students responding responsibly from one culture or the other.

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APPENDICES

Appendix 1   The description of each of the 4 scenarios and the skills required

Tsunami Hazard Scenario
The scenario is designed to be implemented with 10/11th grade students (High / Senior School).

It shows you (the student who is answering the question) on a beach with a younger twin sister and brother. The ocean has suddenly receded, some marine life is stranded on the beach and what appears to be a treasure chest has amazingly become visible.   Several people have begun to move into this newly exposed ocean bottom, attracted by the unusual appearance.

Based on this, you are asked to respond to three tasks:

a. Draw a line on the inset map to represent the direction you would move and explain your reason.
b. List an item of technology, which you would want to have with you if it were possible.

c. Explain why you wish for such technology.

The skills required to respond to this scenario include, but are not limited to the following education through science competence skills:

1. Decision-making; Students must decide how they will react in this situation, it is hoped, they recognize drawback, a warning sign that a tsunami is coming, occurs.
2. Non-routine problem solving; Students imagine they're about to face a tsunami and recognize they have a problem. What is/are the problem(s) and how to solve them.
3. Complex Communication; Students are asked whether and how they would communicate during this scenario (assuming they recognize the tsunami warning and wish to be a responsible citizen).

Students are expected to:

a. recognize the tsunami warning sign (drawback).
b. apply their knowledge of isolines to effectively recognize elevations on the map.
c. synthesize information to solve non-routine problems and make meaningful and socially relevant decisions.

Lightning Hazard Scenario
The scenario is designed to be implemented with 7th/8th grade students (Basic / Middle School).

In part I, students can choose to be at one of two locations on the outset map – 'L1 or L2.' In the scenario, lightning suddenly begins to strike all around. Based on this, students are asked to respond to two tasks:

a. how they would respond by drawing the route to take, and
b. explain their reasoning in the space provided.

In part II, students mark (on the outset map)

a. the symbol '%' at a location they consider the safest location in the event of a lightning strike;
b. mark '#' at the location they would consider to be the most dangerous, and
c. justify their decision.

The skills required to respond to this scenario include, but are not limited to the following 'education through science' skills:

1. Non-routine problem-solving; each lightning scenario begins in an area exposed to lightning.

2. Decision-making concerning how to respond in the event of a severe lightning storm; students decide where to go in the event of a natural hazard such as lightning.

Students are expected to:

a. recognize the manner in which lightning strikes – 'easiest' ('shortest') pathway
b. apply their lightning safety knowledge
c. synthesize information to solve non-routine problems and make meaningful and socially relevant decisions.

Hurricane/Typhoon/Cyclone Scenario
This scenario is designed to be implemented with grade 10th/11th students.
    In part I, you identify your temporary residence, labelled as 'home', near the ocean. You are asked to imagine you are there with your family (mother, father, sister and brother). You determine from your mobile phone that a storm is coming and note that it is recommended to evacuate their home.
    Based on this, you are asked to respond to the following questions:

1. Would you suggest to evacuate as per the advice on the phone? If no, skip to question (4).
2. If evacuating, would you use a car, bicycle, boat, walk, or swim?
3. Sketch the route on the outset map you suggest to take and explain why?
4. How would you communicate or collaborate with other family members?

    In part II, students examine two maps showing a hurricane/cyclone/typhoon about to make landfall, one in the Pacific and another in the Atlantic. Students are asked to

a. consider 'all other factors being equal (such as storm size and intensity, elevation, the shape of the island, the duration of the storm, etc.),' and
b. answer the following: 'indicate and give reasons which storm in your opinion, would cause the most damage'

    The skills required to respond to this scenario include, but aren't limited to the following education through science skills:

1. Decision-making – students are required to make a decision concerning whether they'll evacuate or not, and justify why. Students will also decide which path they will take should they choose to evacuate, where they will go, by what means (car, walking, cycling, etc.);
2. Creative thinking – students need to think creatively to navigate the traffic jam during their evacuation (should they choose to evacuate);

3. Complex Communication/collaboration – students need to consider their other family members when responding in this scenario. Students need to specify how they would communicate and collaborate with them.

Earthquake Scenario
This scenario is designed to be implemented with 7th/8th grade students (Basic /Middle School).

In part I, you are asked to imagine you are in a classroom on the fifth floor of a school building.

The building

a. is built using high quality concrete;
b. has a stairwell, but no elevator.

One student suddenly screams: "Earthquake"! You are told you need to respond to the situation and also asked how you would communicate with others.

The skills required to respond to this scenario include, but aren't limited to the following 'education through science' skills:

1. Decision-making – In this scenario, students need to make decisions regarding their responses to the earthquake;
2. Communication/collaboration – Assume there are 21 people in the room. Students are expected to communicate and collaborate with others in the room while responding in this scenario. Students need to explain the range of procedures they suggest.


■ Agree   Neutral   ■ Disagree
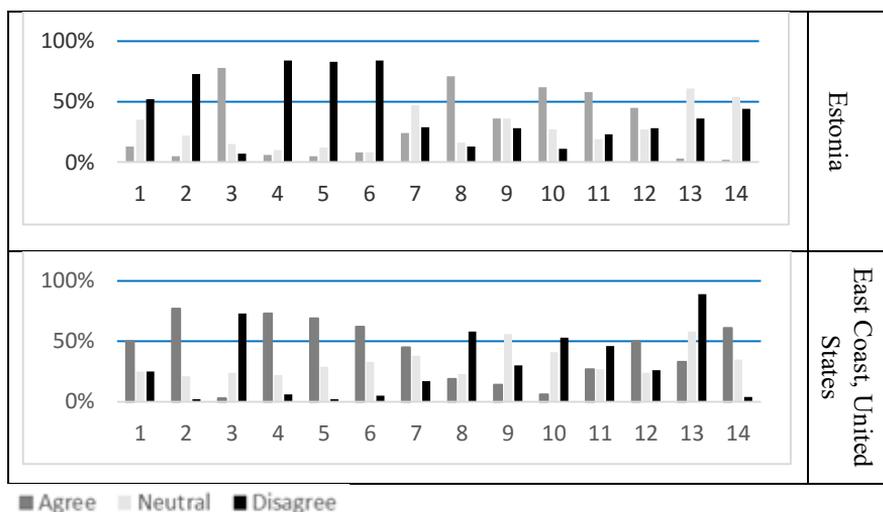
Figure 5   Part B - NOS/NOT competences through natural hazard contexts

Appendix 2   Student responses from piloting in Estonia and the USA

Figure 5 indicates the collective percentage responses for all 14 questions. As an individual student only responded to 4 or 5 questions, this combined data is based on unequal responses to any one question, the data from figure 2 was collapsed into a 3-point scale to allow easier interpretation.

Items were collapsed from a five to three-point scale for simplicity: Agree, Neutral, Disagree. For convenience, Neutral was removed and the above percentages were calculated based on the dichotomy of agree/disagree.
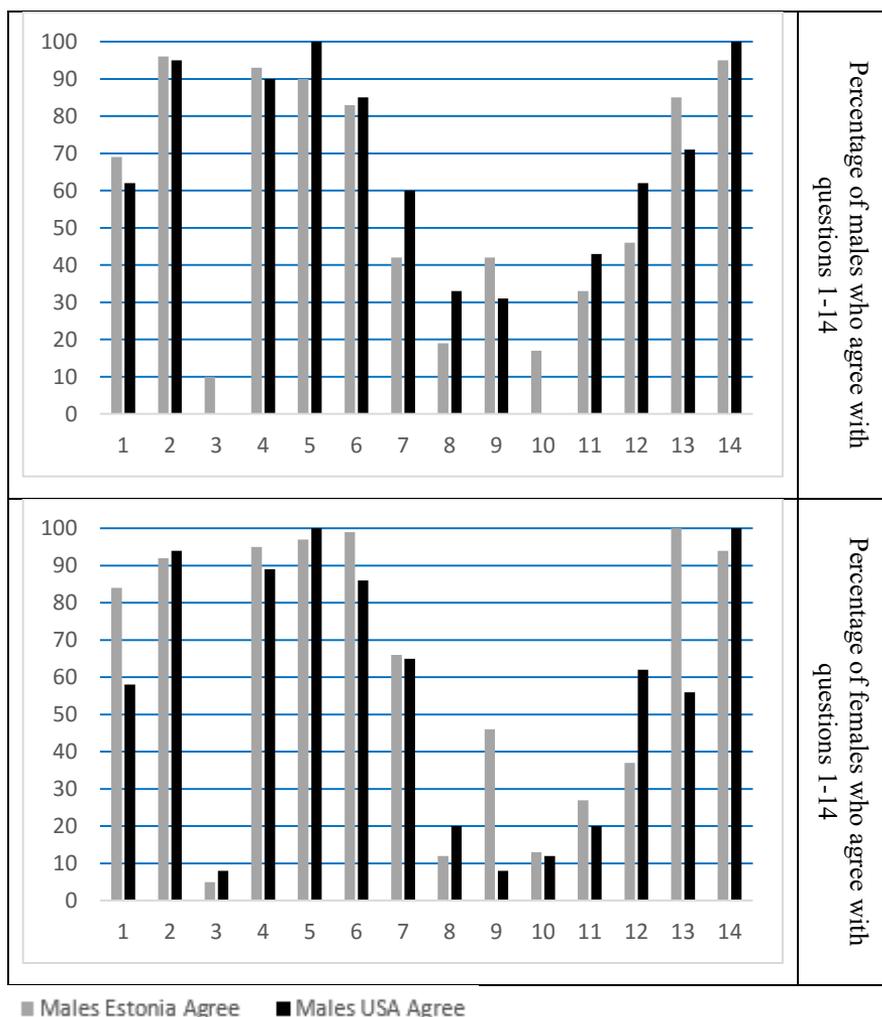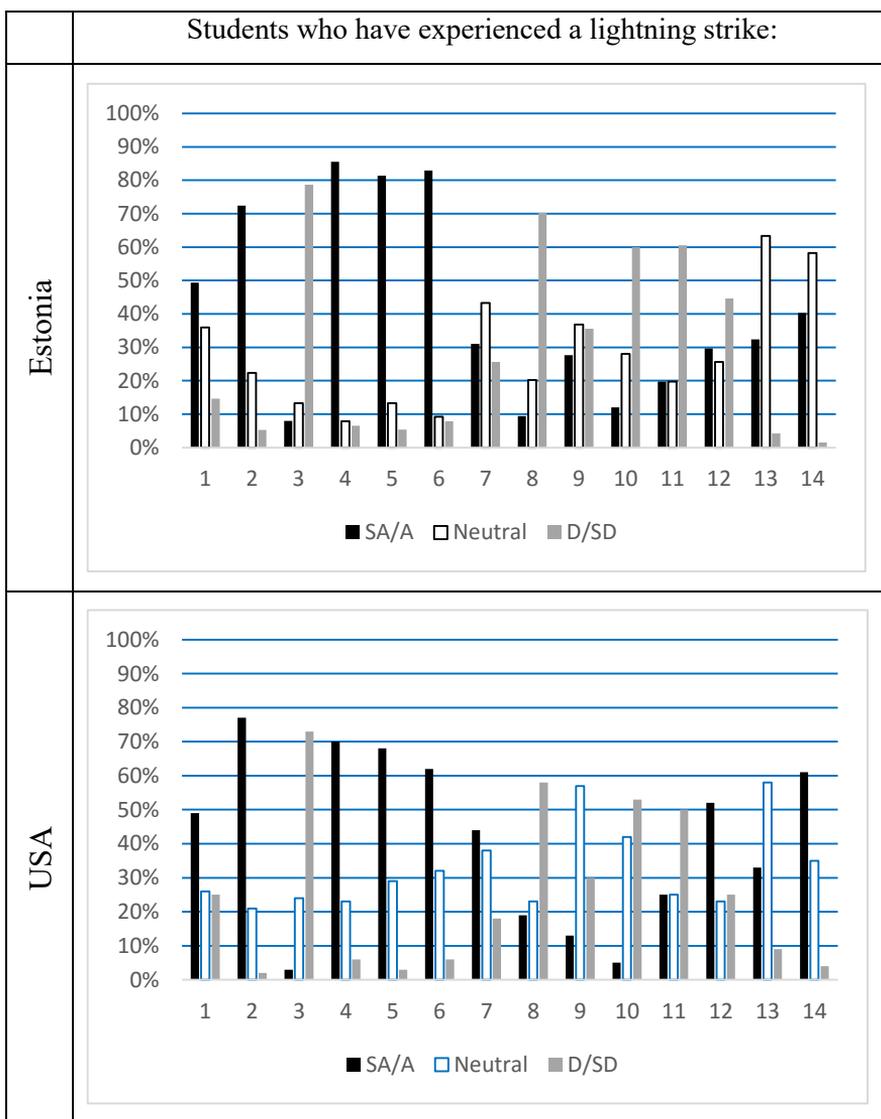
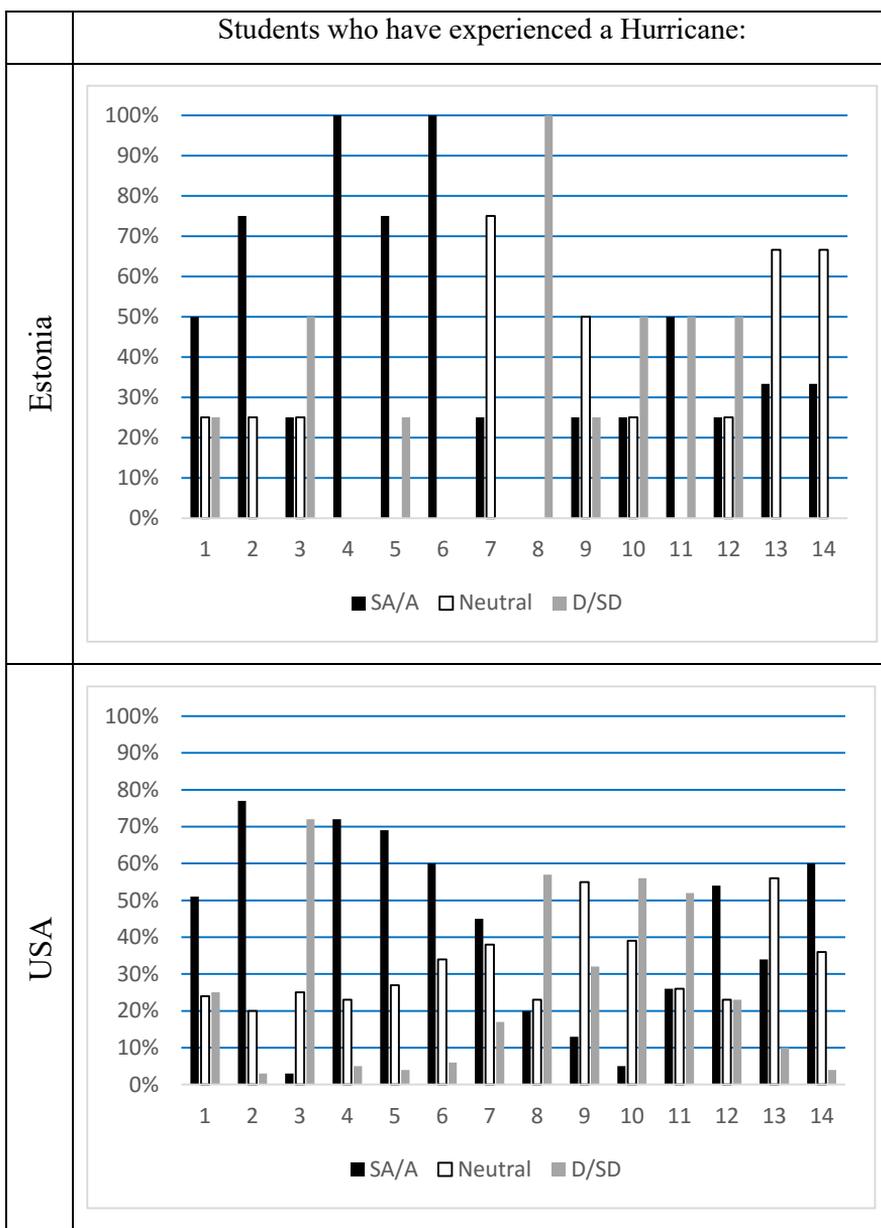**Figure 6** **Part B Percentage data by gender**
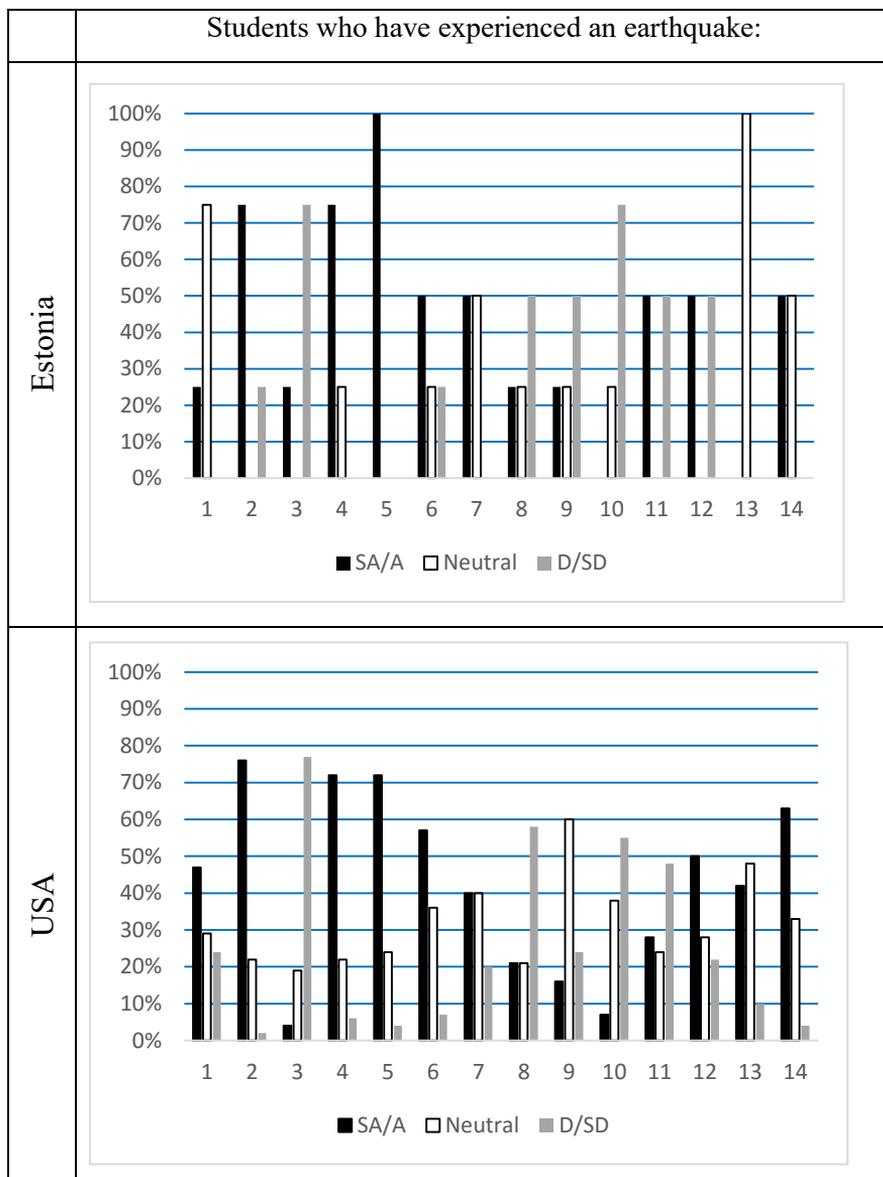
Figure 7-a **Percentage data re- hazard experience related to earthquake**

	Students who have experienced a lightning strike:
Estonia	
USA	

SA/A = Strongly Agree / Agree; S/SD = Agree / Strongly Agree.

Figure 7-b   Percentage data re- hazard experience related to lightning trike

	Students who have experienced a Hurricane:
Estonia	
USA	

SA/A = Strongly Agree / Agree; S/SD = Agree / Strongly Agree.

Figure 7-c   Percentage data re- hazard experience related to hurricane

Table 1-a   Part C - The relationship between science and technology

Estonia	East Coast, United States
Student responses (%)	Student responses (%)
Yes, there is a connection between technology and a cellular phone (85%).	Yes there is a connection between technology and a cellular phone (72%).
Views the relationship between science and technology as bidirectional (12%).	Student views the relationship between science and technology as bidirectional (14%).
Science and technology are independent (3%).	Science and technology are independent (14%).

Table 1-b   Part C - The relationship between science and technology- Results by gender

Estonia	East Coast, United States
Student responses (%)	Student responses (%)
Yes, there is a connection between technology and a cellular phone (96% for males and 95% for females).	Yes there is a connection between technology and a cellular phone (75% males and 75% females).
Views the relationship between science and technology as bidirectional (4% for males and 2% for females).	Student views the relationship between science and technology as bidirectional (18% for males and 5% for females).
Science and technology are independent (0% for males and 3% for females).	Science and technology are independent (7% for males and 20% for females).

Table 1-c   **Part C - The relationship between science and technology- Results by experience**

Estonia	East Coast, United States
Student responses (%)	Student responses (%)
Yes, there is a connection between technology and a cellular phone (100% Hurricane; 100% Earthquake; 95% Lightning).	Yes there is a connection between technology and a cellular phone (73% Hurricanes; 100% Tsunami; 69% Earthquakes; 76% Lightning).
Views the relationship between science and technology as bidirectional (0% Hurricane; 0% Earthquake; 2.5% Lightning).	Student views the relationship between science and technology as bidirectional (12% Hurricanes; 0% Tsunamis; 14% Earthquakes; 12% Lightning).
Science and technology are independent (0% Hurricane; 0% Earthquake; 2.5% Lightning).	Science and technology are independent (12% Hurricanes; 0% tsunami; 17% Earthquakes; Lightning).

*Tsunamis were omitted from Estonian responses as no students indicated they had experienced one.