REFORMING EDUCATION FOR SUSTAINABILITY: THE CONTRIBUTION OF SERIOUS GAMES TO ADDRESS RISK COMMUNICATION FOR RESILIENCE. AN ILLUSTRATIVE EXAMPLE FOCUSED ON TSUNAMI EVENTS

Steven Hawthorn[1]Rui Jesus[2]Mariana Baptista[3]

[1]Department of NOVA LINCS, Faculdade de Ciências e Tecnologia, Univer, NOVA de Lisboa, Portugal
[2]Instituto Superior de Engenharia de Lisboa, Instituto Politécnico de Lisboa, Portugal
[3]Instituto Dom Luiz, Faculdade de Ciências da Universidade de Lisboa, Portugal

ABSTRACT

This article explores the potential contribution of serious games in improving environmental risk communicationin view of reformingEducation for Sustainability(EfS) using a serious game.Following concerns related to the apparent weakness of EfS in providing transitional skills towards resilient and sustainable societies, we present some pedagogical approaches as the basis for learning processes when designing and building a serious game prototype.

We explain why both targeting children and embracing uncertainty in the context of risk is strategic, and why using a serious game as a learning vehicle is particularly relevant in the context of an information and communication technology (ICT) reliant society.The article suggests how the use of key messages in an adventure game format could address other natural hazards. It demonstrates the potential of certain dimensions of ICTs in helping to adapt learning to the classroom environment and in generating both practical skills and long-term positive impacts in society.

KEYWORDS

Education for Sustainability; Disaster Risk Reduction; Uncertainty; Action oriented learning; Skills for sustainability; Serious Games

1. INTRODUCTION

Increasingly, risks and uncertainty need to be integrated into waysof preparing for our future and of making development more sustainable. This was evident during theCovid-19crisis which highlighted our vulnerabilities and lack of resilience. If this integration changes our decision-making paradigm, it is also going to affect the teachingof sustainability, to whom, and at which scale.Whilstsignificant effort has gone into designing ‘Education for Sustainability’,EfS has also generated considerable criticism. Since the term ‘sustainable development’ was first used [1]EfS has not sufficiently improved our resilience [2].

In this paper, we explore how EfS could be improved, using ICTsfocussed on riskcommunication through the application of learning methods that are more experiential, problem-, place-, and skill-based.

Our illustrative example builds on work assessing knowledge gaps [3] and a review of tsunami classroom deployable games [4]. It focuses on risk communication and decision-making in the context of tsunami events. Communicating tsunami risk is challenging due to the infrequent nature of these events, the subsequent lack of community knowledge and the generally low perception of tsunami risk by some coastal communities[5].The key difference in this study is to consider a practical, action-oriented approach to risk communication directed at school children and delivered using a serious game (SG) in a formal education setting. The authors believe this provides a novel contribution.

The article is organised into two parts. The first explores how the issues of risks and uncertainty have become critical in the context of improving EfS. The second focuses on ways in which a tsunami serious game could address the specific pedagogical shortcomings previously identified in existing EfS. The article concludes by critically evaluatingthe potential transferability of an adventure-basedtsunami SG to other natural hazards.

2. THE NEED TO REFORM EFS TO INTEGRATE RISKS AND UNCERTAINTY

Understanding the evolution of EfScan provide insights into potential reforms that not only integrate risk and uncertainty but that also inform new pedagogical approaches.

2.1. From Environmental Education to EFS – A Historical Overview

Overall, three main phases have influenced the way in which we developed our understanding of the terms ‘sustainability’, ‘sustainable development’ and, consequently, EfS [6].

Initially, ‘Environmental Education’ (EE)developed in the 1970s in response to the rise in environmental movements. Although described as interdisciplinary at the Intergovernmental conference on Environmental Education in 1977,EEturned out to be mainly focused on helping learnersto understand the natural environment from a scientific perspectivein view of justifying future action with a high degree of certainty[5].

At the end of the 1980s, tension rose between ESD and Development Education(DE). A potential correlation between environmental damage and economic growth, as well as between the economic wealth of some at the expense of some poorer countries, made an important community of ‘development economists’ and ‘ecological economists’ question our development models and point to the fact that operationalising ‘sustainability’ would imply re-thinking our economic models. This led to defining a new type of development, a ‘sustainable one’, described as a type of development that meets the needs of the present without compromising the ability of future generations to meet their own needs [1]. It also led to the integration of the term ‘development’ into the designation ‘Education for Sustainable Development’ (ESD), which replaced EE.For UNESCO, ESD embraced key sustainable development issues including climate change and disaster risk reduction.Discussions at the Rio UN conferencein 1992led to the publication of ‘Agenda 21’ - the first international document that identified education as an essential tool for achieving sustainable development[7]. The years 2005-2014 were declared the ‘Decade of ESD’, from which a main report emerged [8] followed by the formulation of a series of Sustainable Development Goals (SDGs)[9].

Linking environmental and developmental issues to represent ‘sustainable issues’ within the education system proved to be very ambitious:it led to exploringthe links between human end ecological systems through approaches such as ecological economics, political ecology, and industrial ecology – mainlyin higher education. At the level of primary or secondary schools, however, EfS initiatives often focused on climate change only, keeping ‘sustainability’ either broadand conceptual or focused on very pragmatic day-to-day changes (i.e. home recycling) [10]. Perhaps as a consequence of the way in which the Covid-19 crisis encouraged reflection on contemporary lifestyles; necessitated changes in education practices; and forced greater adoption of ICTs;EfS is taking a new turn.In particular, natural hazard risk is gaining importance in education[11], fitting into the wider debate on science education and risk communication.The combination of thorough coverage of sustainability in school combined with the innovative use of ICTs is an area which the authors consider to be under-researched and is partly addressed as a part of the work.

2.2. New EfS’ Focus on Risks and Uncertainty

The ongoing debate about how to teach scientific concepts to the public [12]includes integration ofrisk into EfS. In the context of disaster risk reduction (DRR), the United Nations (UNDRR) stresses25 targets in 10 of the 17 SDGs,illustrating the need to link DRR and the operationalisation of sustainability.Risk is describedas encompassing: natural hazards (which vary in frequency, intensity, duration); elements at risk (assets, population, environmental features); and vulnerability[13].This frequently adopted description of risks relates them to a number of losses.

In 2015DRR started being linked to sustainable development in three important events: the Sendai Framework for Disaster Risk Reduction (2015−2030); the Sustainable Development Goals (SDGs); and the UN Paris Agreement. Through these, the international community recognised that sustainable development cannot be achieved without accounting forDRR and that natural hazard impacts will erode development gains to date and make the SDGs difficult to achieve[14]. Subsequently UNESCO to recommendedincludingDRR intosustainability education in its Education 2030 Agenda.However, integration of DRR into education raised certain tensions were found –including the “top-down” versus “bottom-up” approach in the generation of local solutions. Although research in DRR has examined its links with resilience and development [15], as well as education styles or curriculum [16], the intersection between both of these in childhood education constitutes a significant research gap (addressed herein)as an emerging agenda for research in EfS and risks.

Whilst natural hazards are often considered as general scientific concepts, and provide scientific information (i.e. the difference between tsunami waves and wind driven waves), DRR organizations go further than advocating simple awareness raising by providing ActionOriented Key Messages(AOKM)which inform decision-making, and outline decision criteria should a natural hazard situation arise [17].

Including these AOKM and embracing uncertaintyiscrucialbecause integrated risk and resilience management includespreparing for the unpredictable[18].EfSoffers interesting opportunitiesfor teaching uncertainty and can include diverse topics including climate change effects orbiodiversity loss impacts [19]. However, for the author, knowing how to deal with‘knowledge uncertainty’ surrounding complex environmental challenges, and making value-based decisions, is a priority.

This should include helping learners to act responsibly and prepare them for making provisional decisions that are based on incomplete information, under significanttime pressure,with

insufficient evidence or unpredictable outcomes [20].Such situations of complex decision-making require developing 'uncertainty competencies' whichinclude being able to prioritise urgent issues, find and use relevant information, judge the credibility of the information sources, formulate a plan of action to deal with uncertainty[19].

Even though several researchers have mentioned the confrontation with uncertainty and pluralism within the context of EfS, there has been very little empirical research to datethat aims to further explicate the concept of teaching learners how to handle this uncertain knowledge in EfS. Research on how to integrate it into learning and teaching processes is therefore still needed. The goal of this article is to address how a SG focussed on one example of natural hazard risk could be applied to the wider issue of teaching EfS to learners in an engaging way. It aims to contribute to that discussion by suggesting a model for a SG that would allow learners to practice taking-action by making decisions under uncertain conditions in a safe and engaging environment.

2.3. New Pedagogical Processes to Address Risks and Uncertainty

2.3.1. New Pedagogical Approaches

Studies which explored the history of environmental education over the past 30 years, showed low levels of awareness of key concepts for sustainability, including the precautionary principle and sustainable development[21]. In view of addressing this, it isworth examininghow certain approaches seem particularly relevant for teaching risk and relating DRR to EfS.

First, the concept of risk can be considered to have multiple meaningsand to be interdisciplinary,resulting in a variety of definitions (nine were presented by [22]). From these, three consistent characteristics emerge: uncertainty, probability and consequence.As such, riskrefers to a future hypothetical event, likely to have a negative consequence.

Decision making in this context of future uncertainty therefore becomes an important skill to acquire and can be practiced usingscenarios. This implies developing the ability to consider alternative responses to a hypothetical situation, to evaluate potential outcomes and to decide on a course of action. It also requires learners to be capable of hypothetical 'what if' reasoning. In terms of cognitive development, and following Bloom's taxonomy [23], such reasoning would rely on Higher Order Thinking Skills (HOTS), which include analysis and evaluation. Activities which useHOTS are considered desirable in education and move away from the traditional knowledge retention, which is often assessed through information recall or completing routine exercises.

Research has stressed the need to better integrate the relevance of knowledge for action and restitution of rights, deploring educational interventions focused on conceptual knowledge or on developing abilities that do not facilitate the ability to use this knowledge to solve local or global problems[24]. In the context of EfS, helping to empower and motivate learners totake action, is a key consideration.

In order to grasp what sustainability means 'on the ground', one has to embrace practical projects and acquire practical skills. Learners need experiential components to understand concepts in depth[25].The stages of such 'experiential learning' include concrete experience (CE), reflective observation (RO), abstract conceptualization (AC) and active experimentation (AE). The approach suggests iterative looping, with the experimentation stage guiding actions in the concrete experience stage. A SG can provide an environment in which to practice this decision-making process.

When learning about risks and DDR, there is also a need to re-establish respect for an adapted relationship with thelocal context without losing a global perspective [4]. Numerous institutional networks have recognized this and have been mobilized to facilitate the integration of school in their territory, in line with programs on ESD[26]. The complex links between education and territory are being progressively integrated into debates on EfS, although, as [27] highlighted,territoriality has only been tackled for fifteen years. This neglect of the context-territorial dimension is being explored in place-based educationwhich, as [28] explains, (1) emerges from the attributes of a place and is specific to geography, ecology, sociology, politics, and other dynamics; (2) is inherently multidisciplinary; (3) is experiential and includes a participatory action or service-learning component geared toward ecological and cultural sustainability; and (4) connects place with self, community, multi-generations and multi-cultures. Complementing place-based learning approaches, a plethora of project-centred educational programmes have been put in place around the worldand helped in identifying common features of EfS and skills for 'sustainabilitylearners'.For instance, materials were developed in the Case Method style - an approach focused on hypothetical scenarios that addressthe uncertainty regarding the impact of different potential courses of actions to increase learners' 'anticipatory competence'[29]. This approach is expected to bolster the normative and strategic competencies of the learners by tackling conflict resolution and the building of trade-offs among participants from different backgrounds [30]. In addition, the Living Schools network, whose curriculum is "founded on understanding the vitality of one's place within the larger landscape as being inextricable from human well being"[30]have identified theskills and competencies that are needed to prepare young generations for the 21st century as: Critical thinking, Communication, Collaboration, Creative problem-solving – but also character education, entrepreneurial mindsets, and using computer-enhanced learning and different types of interactions using digital media[31].In the context of DRR responses, understanding of local environment is helpful in appropriate decision making. For this reason, it is worth investigating the potential that ICTs present to address pedagogical challenges in the context of risks and EfS.

2.3.2. Using ICTs Inpedagogical Reforms in the Context of Risks, DRR and Sustainability

ICTs are a driving force for educational reform, as well as means of promoting shared knowledge in society [32]. The skills and learning outcomes advocated to promote EfScan be facilitatedusing ICTs with schools becoming places of collaborative inquiry and autonomous constructivist learning, with learners using new technologies to solve authentic problems guided by facilitative educators. In addition, simulated environments have provided opportunities for learning for many years (e.g. in the fields of medicine[32]).Simulation refers to a representation or model which is artificial but representative enough to provide educational value and to provide hands-on practice for the learner without exposing themselves or others to undue risk resulting from inexperienced or incompetent operation.Simulated environments can represent a situation which would be impossible to replicate in the real world without exposing learners to significant risk.A Serious Game (SG) would provide a representative physical environment which players can use as the basis for a scenario in which they would have to make decisions. This can add a level of authenticity to the activity which would be lacking in a textbookexercise. The potentials presented by serious games is the focus of the next part of the article.

3. THE SPECIFICITY OF SERIOUS GAMES

While the debate surrounding conceptualization and definition of risk in science education continues, it is evident that SG can provide a highly interactive environment for learners to examine the nature of risk and its consequences in the context of decision-making, without becoming unduly burdened by the complexity of the debate.Gamification has become a popular concept in teaching and training and the last decade has seen an increase in the research interest

in its use [33][34]. Referred to by multiple names, SGs can be considered as pieces of software which have an educational purpose as well as a video game structure, and therefore are entertaining[35]. In this study we consider SGs as being created with a specific educational purpose and not solely intended for amusement [36]. This is an important point as children have a natural propensity to play, and videogames are a medium with which most children are familiar. Increases in motivation to engage in classroom activity when games are played are well documented [37][38] and relevant in the case of problem based situations involving higher order thinking and collaborative learning [39].

In the context of this article, we concentrate on the potentials that SG could havein integrating DRR in EfS with a particular focus on young teenagers. We are paying particular attention to the pedagogical approaches highlighted in the previous section since, in effect:

- SGs provide an ideal environment where ‘what if’ scenarios activities can be undertaken.
- They can help to teachactive decision-making by providing a simulated environment in which decision-making is undertaken and AOKMs are communicated.
- Experiential learningcan be enhanced by the use of a SG environment where different decisions, actions and consequence can help learners consolidate their learning;
- The interactive nature of gamesuses HOTS to analyse natural hazard risk information before making decisions designed to increase their chances of survival.
- Finally, AOKMcan be included in a SG where learners apply the risk information to inform critical decisions in the game. In this context, methods used in SG to convey risk concepts in an engaging way.

This part presentsthe concepts underlying the learning outcomes and skills that are expected to emerge from a SG on risk communication and prevention focused on tsunamis.

3.1. Focusing on SG in The Context of Risks: An Illustrative Example Using Tsunamis

This section introduces the approach taken during the evolution of a game concept and development of a working prototype. It outlines the rationale for selecting specific elements within the game and is organised into the four parts represented in Figure 1.

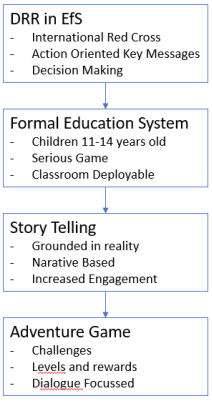

Figure 1 - Evolution of the Approach

As this study was focussed on the creation of a SGwhich, by definition, involves an educational component, the game concept development started by identifying a trusted source and a series of learning objectives. The next stage involved identifying a deployment method which could

provide a supported environment through which the game could be exposed to the largest number of suitable learners. This was the formal education system. Then the most appropriate game genre was considered with the selected audience in mind. Finally, the previous elements led us to conclude that and an adventure game containing challenges was a suitable approach.

3.1.1. DRR as a Starting Point: Focus on Action Oriented Key Messages

The development of the game concept started with the search for a credible DRR organisation to inform the learning objectives. The International Red Cross has a significant experience in the use of SG for communicating risk[40]. Although many educational activities focus on raising tsunami awareness, they lack actionable information which can serve people in emergency situations.

With reference to disasters, 'information shared at the right time, in an understandable format, by trusted sources, can be the most effective life-saving tool in such events'[17].These AOKM, are outlined for twelve specific natural hazard scenarios and provide practical advice for households and schools. These action-focussed messages contain an actioncomponent which can be taken at low cost and could have a significantly beneficial effect should a hazard event occur. In the case of a potential tsunami, the AOKM can also inform critical decisions that need to be made by privateindividuals(such as whether to evacuate or rest in place), as well as criteria which inform decision-making (e.g.How long did the ground shake for?). Referred to as the Natural Warning Signs (NWS), they can indicate the likelihood of a tsunami and act as an early warning indicator. The practical action-oriented focusempowers individuals to make their own decisions rather than wait for instructions. In case of near field tsunamis, warnings from agencies may not arrive in time to inform evacuation decisions[41].The empowering nature of these AOKM and the potential for improved probability of survival led us to use these messages as the primarylearning objectives for the game concept.Previous studies demonstrated a high value associated with local knowledge combined with community participation and an interdisciplinary focus [42]. This community based DRR is considered the most appropriate approach to shaping resilient communities [43].Critical to the success of this approach is the centrality of children, designed to reduce vulnerabilities and impacts to disaster events through educational actions[42].

These considerations influenced the decision to design a SG for deployment through the formal education system focussed on education of young teenagers.

3.1.2. A focus on children and formal education

Children are central to community DRR initiatives. Disproportionally affected by disasters, [44], they can effectively behave as risk communicators [45] and their disaster education can trickle down and inform others in the community[46]. They have a right to information that could inform their own decision-making, particularly in the absence of adults[47].

The United Nations Convention on the Rights of the Child Article 12 recognizes the importance of providing children with information that is appropriate to their age and level of understanding, so that they can make informed decisions. This is particularly appropriate in the cases where children are unsupervised and have responsibility for younger siblings.Childhood is also typically the stage in life where education is provided. Younger children have also been shown to be more open to ideas. These factors led to the conclusion that a classroom deployable game would be suitable for the widest exposure to the most learners.

According to constructivist development theories[48], the final operational stage (11-15) in children's cognitive development facilitates the development of abstract thinking andthe

evaluation of hypothetical situations. As a consequence, this age group is suitable for abstract, hypothetical decision-making based activities and could follow more general natural hazard awareness teaching activities at a younger age.For this reason,11-14-year-old children were chosen as the audience for this game.

A number of tools allow communities to discuss how to prevent hazards from turning into disasters or review and examine experiences that have occurred. Children's stories, comics and fictional stories have been proposed as ways to do this [49][50] as well as 'bottom up' initiatives facilitating inclusion of regional requirements, and community groups [51][52][53]. One method that has been selected in the context of our SG has been story-telling.

3.1.3. Classroom Deployable SG

Given the established internet-based infrastructure for delivering digital assets (i.e. Google Play) to potential players, it is pertinent to address the proposed method of distributing a tsunami SG through the educational infrastructure.While most video games are played during leisure times and many SG are deployed in work place environments, the approach taken here is to design a game for classroom deployment with children between the ages of 11 and 14.Although classroom deployable games are not without challenges [54], classroom deployment through the formal education system was considered desirable for the following reasons.

Given the increased incidence and severity of natural hazard events related to planetary warming [55][56], a game with actionable advice from a recognised disaster authority [17] would consolidate existing awareness raising initiatives and help to equip learners with the information they could use is during a natural hazard emergency. This could significantly increase the likelihood of making good decisions.

The education system is a natural placeto reduce confusing and conflicting information and can play a crucial role in addressing the health and well-being in emergency situations. Schools can provide measured approaches to controversial subject areas, such as the intersection of climate science and natural hazard events and have a significant role to play in children's disaster education [57].The classroom provides a structured environment where follow up support materials, links with other subjects, discussions, and also support can be provided for learners who find natural hazard risk material traumatising.

Denial and fatalistic attitudes can present challenges in teaching subjects such as climate change or natural hazard risks where there is a tendency to question the likelihood of occurrence of an undesirable event. This can result in a dichotomous view of such events into deniers and accepters, which can serve to paralyse the debate [58][59].Using a SG allows the player to be put into a situation similar to one which has already occurred [60]in a format which relies less heavily on the acceptance of the undesirable event premise, hence reducing doubt and denial and increase engagement in the learning process.

An advantage of using a digital SG is the scope for inclusion of innovative ICTs which are becoming available. Future tutoring systems are likely to include personalized and adaptive capabilities which will provide tailored feedback to the learner in accordance with their preferred learning style [61].Personalized and adaptive SG can also provide a more tailored game experience to learners [62]. They can also potentially target areas of core knowledge that the player lacks.

This section has outlined the reasons why the SG was designed for children aged 11-14, for deployment in the classroom,through the formal education system. The following section outlines the choice to use a strong story-based narrative as the core device in the game design.

3.1.4. Story Telling - Using Stories to Facilitate Learning

When addressing the challenge of engaging citizens with EfS, sustainability researchers have experimented with different communication approaches.Story telling has emerged as a strategy for EfS and can provide inaccessible information in a narrative framework by tapping into archetypal patterns for orientation and knowledge transmission [63][64] and facilitate reframing and shared understanding [65].

A significant body of research on stories and storytelling exists which highlights how indigenous communities have used story telling as a way to transfer traditional knowledge and understanding as well as responsibilities for environmental artefacts and legal principles [66], and in the case of tsunami the Indonesian concept of Smong, or immediate evacuation, [67].

Stories represent a fundamental technique for learners to interpret experience. They engage our inclination for connecting characters and events, and making sense of our experiences.Educators can exploit our natural predisposition to enhance learning by securing attention, engaging learner emotions and cognitive abilities through connecting stories to the targeted learning objectives [67].Storytelling as an educational tool facilitates information delivery with a context and provides an emotional dimension to a social experience. This helps knowledge recipients relate the knowledge (in our case AOKM) to their experience (making decisions in the game).

Placing the story into the interactive environment with challenges and learner feedback can be achieved through the use of an approach using an adventure role-playing video game.

Contextualising the SG: The approach taken here grounds the game narrative in reality andlinks the decision-making with the use of challenges.Along with AOKM, a well-documented event took place during the 2004 Indian Ocean earthquake and tsunami [68], which inspired the basis of our SG narrative. The game scenario was inspired by the experience of a 10-year-old girl who recognised the tsunami natural warning signs and was instrumental in warning other beach goers prior to the wave arrival. She was credited with saving a hundred lives.

A realistic scenario where the game is as authentic as possible was preferred. Game characters are not enhanced with magic powers or fantastical abilities and actions in the game relate to the central theme which was applying AOKM risk information to make good evacuation decisions.
Stories also have a logical chronology and provide information about the specific temporal and spatial setting in which they are set. These characteristics are highly relevant in natural hazard events.

3.1.5. Narrative and Character Based

Given the challenges of communicating scientific information to non-scientific audiences and the propensity for denial, a narrative focussed, character-based concept was used for the game. This approach was adopted as young learners tend to identify with characters and engage with stories and we needed a way to communicate and apply the natural warning signs of tsunami.The dialogue between the player and NPC characters provides risk information in the early stage of the game, which must then be applied following the earthquake and the resulting tsunami in the later stage of the game. Players are rewarded for good decision by continuation to the next stage thereby reducing the likelihood of delayed evacuation.

In the case of interactive storytelling, learners are enabled to interact and control the dialogue and discussion thereby providing a degree of control themselves. Using immersive technology such as augmented technology, the learner can become more immersed in the story[69].This principle is embraced with our game although using augmented reality was considered out of scope as this would be challenging for classroom deployment.

SusTelling (Storytelling for Sustainability) can contribute to improving EfS and specifically in our case reaching the learning objective of a SG, but can also help create learners who act in self-determined way[70].

It is this competent self-determination that we are trying to nurture and develop through the use of an adventure SG for tsunami risk communication.

3.2. Working on the Game Design for Our Adventure Game

This section outlines the considerations in the game design and choices untaken during the design process that are intended to address and satisfy the requirements from the previous section.

Game design considerations:The general characteristics of our SG are presented here to provide some context for the reader.The game focusses on the central character Tilia who is visiting her friend Laniat the coastal town of Rica (elevation 3m, pop. 13,968).The town is situated on a flood vulnerable area with a single access road, and a vertical rock escarpment 2km east of the seafront.They visit Lani's grandmother and discuss why the town cemetery was moved to a high point on the escarpment (elevation 55m) and the grandmother tells the Big Wave Story (BWS), which fulfils the function of providing the key information (AOKMs) which the girls have to use during the later challenges.

Figure 2.–Grandma tells the 'Big Wave Story'.

The AOKM mentioned in the BWS include strength and duration of ground shaking; reports of sea movement and noise; time from ground shaking to arrival of the first wave and time taken

from town to high point. Grandma uses the pretext of a visit to the cemetery to encourage the girls to plan a route to the highpoint (thereby meeting the requirements - Learn about history of tsunami in your area; Identify higher ground and routes to get there [17]. They use a picture of the town to identify key landmarks (e.g. tallest building, pedestrian foot bridge and secret shortcut to the high point) during a map challenge and capture a photograph of it on their phone.Later in the game, the characters encounter an earthquake. The challenge is to count the duration of the shaking and collect a few key items before leaving the apartment for an open space (park) to assess the situation.

At the park, the challenge is to assess the situation against the AOKM from the BWS and decide on a course of action.

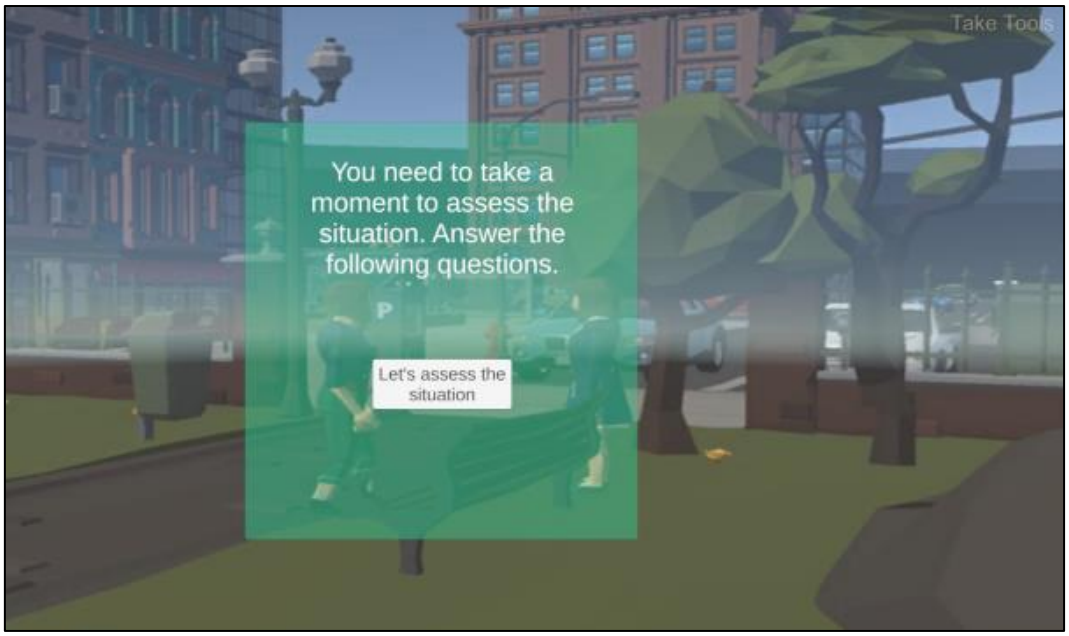

Figure 3 - Assessing the situation at the park

Players can verify their shake duration estimate against the actual shake duration, they can also remember the BWS through a number of memories. From this information they can derive the likelihood of occurrence of a tsunami and an expected time of arrival (ETA) of the first wave. Good decisions are reflected in an increased probability of survival (PoS) score, and unwise decisions (go to the beach and video the wave) result in a decreased PoS.

Following this, the players should decide to evacuate towards the highpoint which takes them past the Skyline Building where it is suggested to vertically evacuate to the top of the building. The challenge is to explain the tsunami NWS to a security guard at the entrance of the building. Without a successful explanation they are not permitted to enter the building. If successful their vertical evacuation attempt is thwarted by the hazards in the building, thereby forcing the player to navigate and climb a secret stairway to the highpoint.

The objective of the game: The primary objective of the game was to provide a safe, interactive environment where learners can apply disaster risk information to practice making good evacuation decisions.In the game, the learner takes the role of decision maker supported by her friend as they move around the town of Rica situated next to the ocean. The player and friend

characters communicate through a dialogue which is shown as speech bubbles on screen. This method allows the learner to witness the dialogue and understand what is happening in the game. The game was conceived to communicate to members of acommunity who perceive tsunami risk to be low or non-existent, rather than a highly aware community who may be familiar with tsunami natural warning signs, and have already taken suitable preparatory actions.The approach followed a survey of learners, which showed an understanding of general tsunami characteristics, but a limited ability of learners to recognise the natural warning signs of tsunami [3] and a literature review of existing classroom deployable, tsunami focussed, serious games [4].

The game adopts an adventure game approach which does not focus on reward mechanics such as coins, or points. Disaster preparedness decision-making requires an investment of effort, typically before the emergency manifests itself (e.g. putting on a seatbelt) and results in a future reward of reduced negative health impact (injury) if the event occurs. In this case, monetary reward is considered unrealistic. Instead, the PoS (Probability of Survival) score is adopted as a proxy for health score. The objective, for the player, is to survive, within a time constraint.

The following figure shows the general framework developed for this tsunami game concept and its transferability to other natural hazard scenarios. It provides a reusable framework for the development of risk communication SGs for natural hazards outlined in the literature IFRC. It is believed that game function reusability could be derived from development of modular functions required across different games. Currently the diagram indicates the main events for each game scene. However, main events can contain nested sub-events which follow a similar - stimulus – information process – action response pattern. More research could focus on the development of similar SG in an EfS context.

While concerns were raised that the game concept was not stimulating enough for learners (with too much reading of the dialogue), the initial findings following informal beta testing of the prototype made the following suggestions.

- Delivering DRR risk messages (AOKM) to learners through a storytelling format is sufficiently engaging that it should not be dismissed in favour of more rewards focussed approach, where learners are immediately rewarded for making appropriate disaster response decisions.
- The adventure game concept is one valid approach to designing a tsunami risk SG. It can encompass problem solving activities (such as calculating evacuation time) which requires consideration and use of the AOKM by the game users.
- Future work needs to formalise the play testing feedback using a posttest player experience questionnaire of the prototype to quantify and assess usability and player experience include learning effectiveness.
- Assessment of the semantic similarity between action messages for the twelve different natural hazard scenarios will inform the question of whether this approach would be reusable for the other scenarios covered by the Red Cross, such as wildfire and flooding.
- Designing a serious game activity addressing the notions of risk and uncertainty and helping the learner to practice the skills required to face an uncertain emergency situation provides a useful contribution to education for sustainability and presents it in a practical context

The authors believe that the article provides a valuable contribution to the issue of communicating natural hazard risk in the context of teaching EfS. It validates the current adventure game approach and suggests a model as a foundation for more detailed work as a way to combine EfS, communicating natural hazard risk in a practical way and using ICTs. However, the limited scale of the study and the lack of formal data capture needs to be addressed as part of

ongoing work. This will provide a more rigorous validation of the game concept and provide an insight into the learning effectiveness of this type of SG.

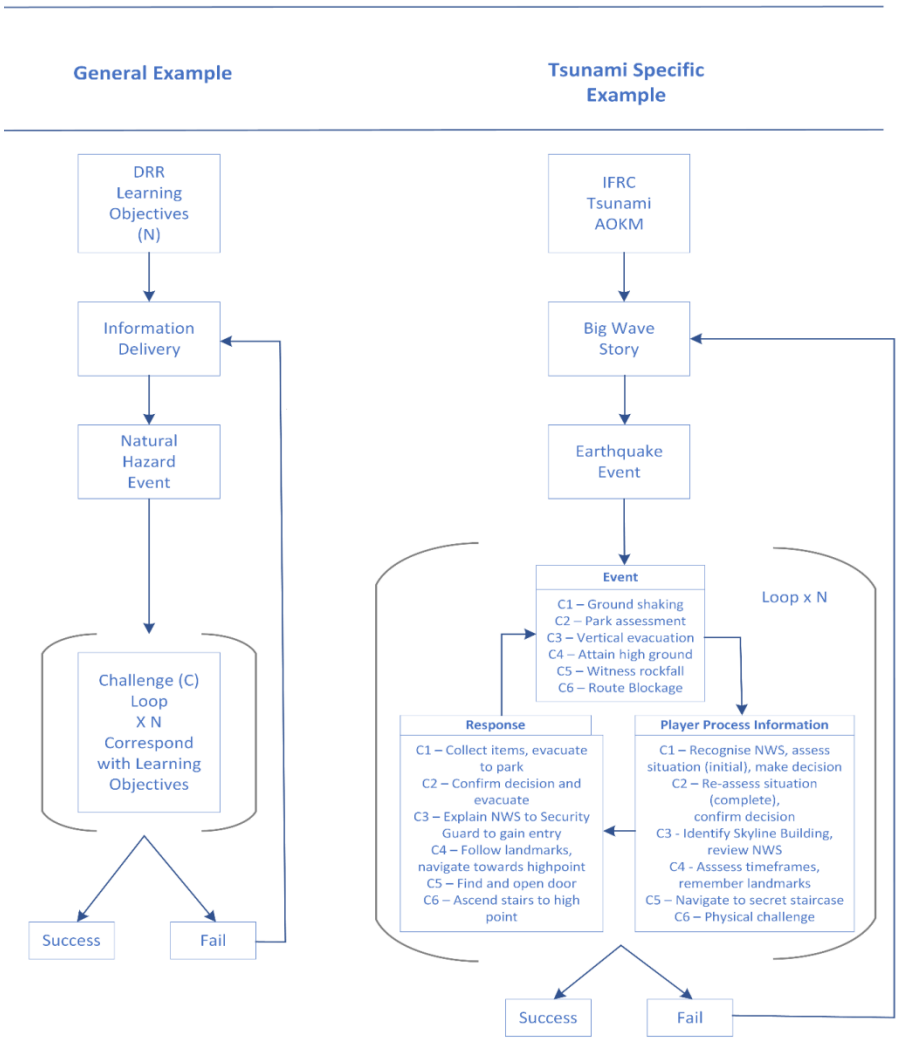

Figure 4 - Game Concept Transferability to other natural hazard events

4. CONCLUSION

As the history of EfS illustrates, various educational phases have attempted to integrate particular dimensions of 'sustainability' or 'sustainable development' into education. Risk and uncertainty have now started to be taken into consideration, especially postCovid-19. This is marking the beginning of what could be a significant and crucial new phase in the reform of EfS, in which sustainability is being more strongly connected to resilience and in which educational approaches are progressively moving away from focusing on scientific certainty. EfS, in this context, and especially in situations of DRR, changes its focus in order to preparing learners to un-predictable situations in which they will need entirely new skills.

This new learning context also includes a very broad and varied use of ICTs –enabling access to more information, perspectives, participants, but also new ways of learning and envisaging knowledge on sustainability as including not only concepts but also skills. The article reviews the potentials that ICTs present in enhancing experiential, project-based learning, the better

understanding of a context, or problem-based, scenario-focused learning activities. It shows how ICTs can respond well to the new needs identified to reform EfS and make it better adapted to current societal needs.

The particular illustrative example this research focuses on is the area of serious games and, more particularly, one that has been developed to respond to the need of learners to prepare for and understand better risks represented by a tsunami event. This is typically a situation that is difficult to imagine and SG can address particularly well the pedagogical requirements for such a context. These include putting the learner 'in context' - that is, in a (simulated) situation in which he/she can implement 'action-oriented learning skills' -; motivating the learning process by involving learners through an interactive process involving dialogues, story-telling, narratives and characters; enhancing the learners' awareness of their surrounding by organising activities that link the observation of the geographical environment with maps reading and the recognition of main landmarks.

The article concludes that SGs seem particularly well adapted to linking a very rich ICT learning environment with new learning outcomes related to sustainability such as risk communication and teaching decision-making under conditions of uncertainty. This is because SGs provide a safe interactive, engaging, character focussed, narrative based environment for the exploration of risk issues.The research also highlights the fact that children constitute a particularly interesting target audience for learning on these issues and in this way, and that schools constitute a particularly relevant institutional setting in which teachers can become facilitators to empower learners to acquire new skills.

Although the focus of our SG is tsunamis, the preparedness to many other natural hazards could also be taught through such SG. More importantly, this article demonstrates that new pedagogical supports are needed so as to address the shortcomings of EfS and that SG could address this issue in relevant ways since pedagogical processes that can be developed using SGs parallel many theoretical findings on how EfS needs to be improved. More research is needed to potentially parallel other sustainability hot topics to SG learning supports.

CONFLICT OF INTEREST DECLARATION

No potential competing interests were reported by the authors.

ACKNOWLEDGEMENTS

This work is supported by NOVA LINCS (UIDB/04516/2020) with the financial support of FCT.IP and by the project IPL/2022/MOBILIZE_ISEL. The authors would also like to acknowledge the contribution of Dr.Sandrine Simon in the review of this manuscript.

REFERENCES

[1] W. Visser and G. H. Brundtland, "Our Common Future ('The Brundtland Report'): World Commission on Environment and Development," 1987. doi: 10.9774/gleaf.978-1-907643-44-6_12.

[2] A. Lautensach, "Educating for Sustainability: Curriculum Reform in the Age of Environmental Crisis," *Sustainability*, vol. 1st World, no. November, pp. 1–15, 2011, [Online]. Available: https://sciforum.net/manuscripts/596/original.pdf

[3] S. Hawthorn, R. Jesus, and M. A. Baptista, "Tsunami Risk Communication: Assessing Knowledge Gaps and Suitable Serious Games," *Sci. Tsunami Hazards*, vol. 40, no. 1, pp. 54–76, 2022, [Online]. Available: http://www.tsunamisociety.org/STHVol41N1Y2022.pdf

[4] S. Hawthorn, R. Jesus, and M. A. Baptista, "A Review of Digital Serious Games for Tsunami Risk Communication," *Int. J. Serious Games*, vol. 8, no. 2, pp. 21–47, 2021, doi: https://doi.org/10.17083/ijsg.v8i2.411.

[5] L. Cugliari, A. Cerase, and A. Amato, "Tsunami risk perception, a state-of-the-art review with a focus in the NEAM region," *Front. Earth Sci.*, vol. 10, no. December, pp. 1–25, 2022, doi: 10.3389/feart.2022.995536.

[6] S. Simon, "A New Phase in the History of Education for Sustainability. The Emergence of Territorial Education in a Post-Covid Recovery Period," *World J. Educ. Res.*, vol. 9, no. 3, p. p75, 2022, doi: 10.22158/wjer.v9n3p75.

[7] UN, "UN Conference on Environment and Development," New York, 1992. doi: 10.4135/9781412971867.n128.

[8] C. Buckler and H. Creech, *Shaping the future we want: UN Decade of Education for Sustainable Development*. Paris: UNESCO, 2014. [Online]. Available: https://unesdoc.unesco.org/ark:/48223/pf0000230171

[9] UN, "Transforming our world: The 2030 Agenda for Sustainable Development. United Nations General Assembly Resolution A/RES/70/1.," New York, 2015. [Online]. Available: https://sdgs.un.org/2030agenda

[10] R. Wade, "Education for sustainability: Challenges and opportunities," in *Policy & Practice A Development Education Review*, J. Coriddi, Ed. Lisburn, 2008, pp. 30–49. [Online]. Available: https://www.researchgate.net/publication/284935593_Education_for_sustainability_Challenges_and_opportunities

[11] B. Komac *et al.*, "Risk education and natural hazards. CapHaz-Net WP6 Report.," Ljubljana, 2010. [Online]. Available: http://caphaz-net.org/outcomes-results/CapHaz-Net_WP6_Risk-Education

[12] R. F. Kenny *et al.*, "The public and effective risk communication," *CEUR Workshop Proc.*, vol. 1, no. 2, pp. 391–397, 2018, doi: 10.1016/j.toxlet.2003.12.049.

[13] UNDRO, "Natural Disasters and Vulnerability Analysis.," Geneva, Switzerland, 1979. [Online]. Available: https://digitallibrary.un.org/record/95986?ln=en

[14] J. Wen, C. Wan, Q. Ye, J. Yan, and W. Li, "Disaster Risk Reduction, Climate Change Adaptation and Their Linkages with Sustainable Development over the Past 30 Years: A Review," *Int. J. Disaster Risk Sci.*, vol. 14, no. 1, pp. 1–13, 2023, doi: 10.1007/s13753-023-00472-3.

[15] C. Béné, A. Newsham, M. Davies, M. Ulrichs, and R. Godfrey-Wood, "Review article: Resilience, poverty and development," *J. Int. Dev.*, vol. 26, no. 5, pp. 598–623, 2014, doi: 10.1002/jid.2992.

[16] S. Gough and A. Stables, "Interpretation as Adaptation: Education for Survival in Uncertain Times," *Curric. Inq.*, vol. 42, no. 3, pp. 368–385, Apr. 2012, [Online]. Available: http://www.jstor.org/stable/23252434

[17] IFRC; Save the Children International, "Public awareness and public education for disaster risk reduction: Action-oriented key messages for households and schools - 2nd ed.," 2018. [Online]. Available: https://www.ifrc.org/sites/default/files/PAPE-2.0-English.pdf

[18] R. Pirani and L. Tolkoff, "Lessons from Sandy: Federal policies to build climate-resilient coastal regions.," Cambridge, MA, 2015.

[19] R. Tauritz, "A pedagogy for Uncertain Times," in *Research and Innovation in Education for Sustainable Development. Exploring collaborative networks, critical characteristics and evaluation practices*, W. Lambrechts and J. Hindson, Eds. Vienna, Austria: Environment and School Initiatives, 2016, pp. 90–105. [Online]. Available: https://www.researchgate.net/publication/291687541_A_pedagogy_for_Uncertain_Times

[20] R. Barnett, "Learning for an unknown future," *High. Educ. Res. Dev.*, vol. 31, no. 1, pp. 65–77, Feb. 2012, doi: 10.1080/07294360.2012.642841.

[21] J. Fien, "EDUCATION FOR SUSTAINABILITY-Educational Policy and Practice for Sustainable Development," in *Encyclopedia of Life Support Systems EOLSS*, Paris: EOLSS, UNESCO, 2020. [Online]. Available: https://www.eolss.net/sample-chapters/c11/e6-61-05-01.pdf

[22] L. Schenk *et al.*, "Teaching and discussing about risk : seven elements of potential significance for science education," *Int. J. Sci. Educ.*, vol. 0693, no. 41:9, pp. 1271–1286, 2019, doi: 10.1080/09500693.2019.1606961.

[23] T. Sarifah and A. Syed, "Application of the Bloom ' s Taxonomy in Online Instructional Games," *Int. J. Acad. Res. Bus. Soc. Sci.*, vol. 7 (4), no. May, pp. 1–8, 2017, doi: 10.6007/IJARBSS/v7-i4/2910.

[24] V. M. Cabello, K. D. Véliz, A. M. Moncada-Arce, M. I. García-Huidobro, and F. Juillerat, "Disaster

risk reduction education: Tensions and connections with sustainable development goals," *Sustain.*, vol. 13, no. 19, pp. 1–18, 2021, doi: 10.3390/su131910933.

[25] P. Meera, M. L. McLain, K. Bijlani, R. Jayakrishnan, and B. Rao, "Serious Game on Flood Risk Management," 2016, pp. 197–206. doi: 10.1007/978-81-322-2553-9_19.

[26] C. A. Francis *et al.*, "Innovative Education in Agroecology: Experiential Learning for a Sustainable Agriculture," *CRC. Crit. Rev. Plant Sci.*, vol. 30, no. 1–2, pp. 226–237, Jan. 2011, doi: 10.1080/07352689.2011.554497.

[27] P. Champollion, "Education and Territory : A Conceptual Framework," *Sisyphus - J. Educ.*, vol. 3, no. 2, pp. 12–27, 2015, [Online]. Available: https://revistas.rcaap.pt/sisyphus/article/view/7882

[28] H. Keeler, "Considering the Urban Farm program and the role of place-based experiential education in the pedagogy of landscape Architecture," University of Oregon, 2011.

[29] C. Albert, C. Von Haaren, J. C. Vargas-Moreno, and C. Steinitz, "Teaching Scenario-Based Planning for Sustainable Landscape Development: An Evaluation of Learning Effects in the Cagliari Studio Workshop," *Sustainability*, vol. 7, no. 6, pp. 6872–6892, 2015, doi: 10.3390/su7066872.

[30] K. Brundiers, A. Wiek, and C. L. Redman, "Real-world learning opportunities in sustainability: from classroom into the real world," *Int. J. Sustain. High. Educ.*, vol. 11, no. 4, pp. 308–324, Jan. 2010, doi: 10.1108/14676371011077540.

[31] I. Mulà *et al.*, "Catalysing Change in Higher Education for Sustainable Development," *Int. J. Sustain. High. Educ.*, vol. 18, no. 5, pp. 798–820, Jan. 2017, doi: 10.1108/IJSHE-03-2017-0043.

[32] A. H. Al-Elq, "Simulation-based medical teaching and learning," *J. Family Community Med.*, vol. 17, no. 1, pp. 35–40, 2010, doi: 10.4103/1319-1683.68787.

[33] Y. Zhonggen, "A Meta-Analysis of Use of Serious Games in Education over a Decade," *Int. J. Comput. Games Technol.*, vol. 2019, no. 3, pp. 1–9, 2019, doi: 10.1155/2019/4797032.

[34] C. K. W. Tan and N.-A. Hidayah, "Serious Games for Environmental Education," *Integr. Conserv.*, vol. 2, no. February 2023, pp. 19–42, 2023, doi: 10.1002/inc3.18.

[35] D. Djaouti, J. Alvarez, and J.-P. Jessel, "Classifying Serious Games," in *Handbook of Research on Improving Learning and Motivation through Educational Games: Multidisciplinary Approaches*, no. January, Patrick Felicia, Ed. 2011, pp. 118–136. doi: 10.4018/978-1-60960-495-0.ch006.

[36] L. M. van der Lubbe, C. Gerritsen, M. C. A. Klein, and K. V. Hindriks, "Empowering vulnerable target groups with serious games and gamification," *Entertain. Comput.*, vol. 38, no. October 2020, p. 100402, 2021, doi: 10.1016/j.entcom.2020.100402.

[37] M. Kalogiannakis, S. Papadakis, and A. I. Zourmpakis, "Gamification in science education. A systematic review of the literature," *Educ. Sci.*, vol. 11, no. 1, pp. 1–36, 2021, doi: 10.3390/educsci11010022.

[38] A. I. Zourmpakis, M. Kalogiannakis, and S. Papadakis, "Adaptive Gamification in Science Education: An Analysis of the Impact of implementation and Adapted game Elements on Students' Motivation," *Computers*, vol. 12, no. 7, 2023, doi: 10.3390/computers12070143.

[39] M. Moradi and N. F. B. M. Noor, "The Impact of Problem-Based Serious Games on Learning Motivation," *IEEE Access*, vol. 10, pp. 8339–8349, 2022, doi: 10.1109/ACCESS.2022.3140434.

[40] H. R. Parker *et al.*, "Using a Game to Engage Stakeholders in Extreme Event Attribution Science," pp. 353–365, 2016, doi: 10.1007/s13753-016-0105-6.

[41] G. A. Papadopoulos, E. Lekkas, and K. Katsetsiadou, "GeoHazards Tsunami Alert Efficiency in the Eastern Mediterranean," *GeoHazards*, vol. 1(1), no. May, pp. 44–60, 2020, doi: https://doi.org/10.3390/geohazards1010005.

[42] M. B. De Mendonca, T. C. Da-Silva-Rosa, and A. R. Bello, "Transversal integration of geohydrological risks in an elementary school in Brazil: A disaster education experiment," *Int. J. Disaster Risk Reduct.*, vol. 39, no. 101213, 2019, doi: https://doi.org/10.1016/j.ijdrr.2019.101213.

[43] G. C. Nche, H. C. Achunike, and A. B. Okoli, "From climate change victims to climate change actors: The role of eco-parenting in building mitigation and adaptation capacities in children," *J. Environ. Educ.*, vol. 50, no. 2, pp. 131–144, Mar. 2019, doi: 10.1080/00958964.2018.1553839.

[44] C. Kousky, "Impacts of Natural Disasters on Children," *Futur. Child.*, vol. 26, no. 1, pp. p73-92, 2016, doi: http://dx.doi.org/10.1353/foc.2016.0004.

[45] T. Mitchell, T. Tanner, and K. Haynes, "Children as agents of change for Disaster Risk Reduction : Lessons from El Salvador and the Philippines .," Brighton, 1, 2009. [Online]. Available: https://www.researchgate.net/publication/228376320_Children_as_Agents_of_Change_for_Disaster_Risk_Reduction_Lessons_from_El_Salvador_and_the_Philippines

[46] B. Wisner, "Let Our Children Teach Us! A Review of the Role of Education andKnowledge in Disaster Risk Reduction," 2006. [Online]. Available: https://www.preventionweb.net/files/609_10030.pdf

[47] A. Nylund, "Children's Constitutional Rights in the Nordic Countries," in *Children's Constitutional Rights in the Nordic Countries*, no. November, 2019, pp. 201–224. doi: 10.1163/9789004382817.

[48] P. Bélanger, "Three Main Learning Theories," in *Theories in Adult Learning and Education*, R. Egetenmeyer, Ed. Opladen & Farmington Hills, MI: Verlag Barbara Budrich, 2011, pp. 17–34. doi: 10.2307/j.ctvbkjx77.6.

[49] M. T. Carone and F. Marincioni, "From tale to reality: Geographical differences in children's flood-risk perception," *Area*, vol. 52, no. 1, pp. 116–125, 2020, doi: https://doi.org/10.1111/area.12552.

[50] J. Sharpe and Y. O. Izadkhah, "Use of comic strips in teaching earthquakes to kindergarten children," *Disaster Prev. Manag. An Int. J.*, vol. 23, no. 2, pp. 138–156, 2014, doi: 10.1108/DPM-05-2013-0083.

[51] L. Kaiser and K. Boersen, "Kura e tai aniwhaniwha (schools and tsunami): Bi-cultural and studentcentred tsunami education in aotearoa New Zealand," *Aust. J. Emerg. Manag.*, vol. 35, no. 2, pp. 58–65, 2020.

[52] S. Shohieb, "CDMG: Crises and Disasters Management Game (Video Game to Teach Arab Children How to Handle Emergencies and Crises)," in *2018 7th International Conference on Software and Computer Applications (ICSCA 2018)*, Feb. 2018, pp. 264–268. doi: 10.1145/3185089.3185147.

[53] A. L. Williams, A. Bingley, M. Walker, M. Mort, and V. Howells, "That's where I first saw the water: Mobilizing children's voices in UK flood risk management," *Transfers*, vol. 7, no. 3, pp. 76–93, 2017, doi: 10.3167/TRANS.2017.070307.

[54] P. Backlund and M. Hendrix, "Educational games - Are they worth the Effort?: A literature survey of the effectiveness of serious games," *2013 5th Int. Conf. Games Virtual Worlds Serious Appl. VS-GAMES 2013*, no. December, 2013, doi: 10.1109/VS-GAMES.2013.6624226.

[55] M. Coronese, F. Lamperti, K. Keller, F. Chiaromonte, and A. Roventini, "Evidence for sharp increase in the economic damages of extreme natural disasters," *Proc. Natl. Acad. Sci. U. S. A.*, vol. 116, no. 43, pp. 21450–21455, 2019, doi: 10.1073/pnas.1907826116.

[56] A. Fothergill, "Children, Youth, and Disaster," *Nat. Hazard Sci.*, no. July 2017, pp. 1–26, 2017, doi: https://doi.org/10.1093/acrefore/9780199389407.013.23.

[57] H. Seddighi *et al.*, "School-Based Education Programs for Preparing Children for Natural Hazards : A Systematic Review School-Based Education Programs for Preparing Children for Natural Hazards : A Systematic Review," *Disaster Med Public Heal. Prep.*, vol. Jun;, no. 16(3):, pp. 1229-1241., 2022, doi: 10.1017/dmp.2020.479.

[58] F. I. Aksa, S. Utaya, S. Bachri, and B. Handoyo, "The role of knowledge and fatalism in college students related to the earthquake-risk perception," *Jamba J. Disaster Risk Stud.*, vol. 12, no. 1, pp. 1–6, 2020, doi: 10.4102/jamba.v12i1.954.

[59] C. Bretter and F. Schulz, "Why focusing on 'climate change denial' is counterproductive," *Proc. Natl. Acad. Sci. U. S. A.*, vol. 120, no. 10, pp. 1–3, 2023, doi: 10.1073/pnas.2217716120.

[60] R. Omira, M. A. Baptista, and S. Mellas, "The November 1st , 1755 Tsunami in Morocco : Can Numerical The November , 1 st , 1755 Tsunami in Morocco : Can Numerical Modeling Clarify the Uncertainties of Historical Reports ?," no. May 2017, 2012, doi: 10.5772/51864.

[61] A. Essa, "A possible future for next generation adaptive learning systems," *Smart Learn. Environ.*, vol. 3, no. 16, pp. 1–24, 2016, doi: 10.1186/s40561-016-0038-y.

[62] A. Streicher and J. D. Smeddinck, "Personalized and Adaptive Serious Games," in *Entertainment Computing and Serious Games*, no. October, 2016, pp. 1–47. doi: 10.1007/978-3-319-46152-6.

[63] D. S. Wilson, "Evolutionary Social Constructivism," in *The Literary Animal: evolution and the nature of narrative*, J. Gottschall and D. S. Wilson, Eds. Northwestern University Press, 2005, pp. 1–17. doi: 10.2307/j.ctvw1d5h1.

[64] M. F. Dahlstrom, "Using narratives and storytelling to communicate science with nonexpert audiences," *Proc. Natl. Acad. Sci. U. S. A.*, vol. 111, pp. 13614–13620, 2014, doi: 10.1073/pnas.1320645111.

[65] L. W. Black, "Framing Democracy and Conflict Through Storytelling in Deliberative Groups," *J. Deliberative Democr.*, vol. 9, no. 1, 2013, doi: 10.16997/jdd.153.

[66] K.-E. Sveiby, "Aboriginal principles for sustainable development as told in traditional law stories," *Sustain. Dev.*, vol. 17, no. 6, pp. 341–356, 2009, doi: https://doi.org/10.1002/sd.389.

[67] A. Rahman, A. Sakurai, S. Sutton, M. Syahbandir, and N. Nofriadi, "Smong means more than tsunami: The understanding of tsunami in the Indonesian context," *E3S Web Conf.*, vol. 340, pp. 1–6, 2022, doi: 10.1051/e3sconf/202234003010.

[68] S. Rajib, T. Yukiko, R. G. Qi, and S. Koichi, "Chapter 1 Disaster Education: An Introduction," in *Disaster Education*, vol. 7, R. Shaw, K. Shiwaku, and Y. Takeuchi, Eds. Emerald Group Publishing Limited, 2011, pp. 1–22. doi: 10.1108/S2040-7262(2011)0000007007.

[69] S. Baldwin and Y. H. Ching, "Interactive Storytelling: Opportunities for Online Course Design," *TechTrends*, vol. 61, no. 2, pp. 179–186, 2017, doi: 10.1007/s11528-016-0136-2.

[70] D. Fischer, H. Selm, A. Sundermann, and M. Storksdieck, "Storytelling for sustainability : A definition and its implications for education and communication," *Storytell. Sustain. High. Educ.*, pp. 38–51, 2020, [Online]. Available: https://www-taylorfrancis-com.ezproxy.library.wur.nl/chapters/edit/10.4324/9780429291111-5/storytelling-sustainability-daniel-fischer-hanna-selm-anna-sundermann-martin-storksdieck