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Exploring the Use of Experiential Learning Methods to Increase CBRNe Awareness and Emergency Preparedness of Children

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ABSTRACT

In recent years, there has been an increase in chemical, biological, radiological, nuclear, and explosive incidents, often involving or specifically targeting children. These emerging threats pose a significant risk to the physical, psychological, and social wellbeing of children and can cause damaging effects on their development and growth. Children are more susceptible to the lethal effects of CBRNe agents and require increased protection, specialized intervention and medical countermeasures, and expert mental health support post-incident. The Hyogo Framework established a widely adopted international commitment to educating children about disasters, through which many nations have implemented disaster risk reduction education platforms focused on increasing their knowledge about potential hazards. However, few countries have begun to explore the benefits of introducing a comprehensive CBRNe awareness and preparedness curriculum to children. Studies have shown that experiential learning methods offer a highly engaging and immersive learning experience and increase educational outcomes. This work aims to explore the potential benefits of developing an interactive educational tool to introduce basic skills to prepare children and communities against CBRNe incidents.

1. INTRODUCTION

Children are among the most vulnerable members of society. They are also the most resilient if provided with a healthy support system and tools which foster positive development and growth. Experiencing a traumatic disaster or living in a constant state of danger poses a significant threat to the psychological and physical wellbeing of children in any socio-economic context [1]. Throughout the last century, children have experienced life-altering tragedies stemming from accidental or intentional man-made disasters. Recent and emerging humanitarian crises have increased global awareness on the harmful effects of chemical, biological, radiological, nuclear and explosive (CBRNe) emergencies through incidents such as the use of improvised explosive devices (IEDs) on schools in Myanmar, chemical attacks targeting children in Syria, armed violence and explosives in Ukraine, the COVID-19 pandemic, and many others [2-6]. From a medical standpoint, children are typically more susceptible to the harmful and lethal effects of CBRNe substances, and their exposure to these events causes increased long-term physical and psychological damage compared to adults [1, 7]. In many nations, disaster awareness and safety are taught to children to prepare and protect them against natural disasters, such as hurricanes, tornadoes, tsunamis, floods, and earthquakes, or in the event of an active shooter attack in schools. To date, little research has been done to explore the benefits of introducing basic CBRNe preparedness skills to children. By increasing awareness of the potential hazards and effects of CBRNe risks, children will learn to recognize unknown or unexpected dangers which may foster greater positive outcomes in the event of an emergency. Consequently, some studies suggest that increased public awareness results in better-quality emergency prevention planning and improves crisis management and response conditions by reducing the overwhelming impact on public health systems, decreasing the number of preventable fatalities, and enhancing the expanse of available resources in recovery operations [8].

2. METHODOLOGY

The goal of this study was to investigate the potential effectiveness of increasing the knowledge and preparedness of children against CBRNe incidents. This work was conducted using qualitative methods, combining extensive desk research

on the history and consequences of CBRNe incidents involving children, with a comparative review on pedagogical teaching methods. The study also included a systematic evaluation of 30 case studies on currently existing international disaster risk reduction education (DRRE) programs. The comparative review of pedagogical teaching methods aimed at identifying the most appropriate style for application to a CBRNe disaster education curriculum. Based on this review, experiential learning theory was identified as the most effective pedagogical method to achieve this purpose. The results were used to propose a framework by which a CBRNe preparedness curriculum could potentially be implemented by local, regional, and national authorities, thereby decreasing the existing knowledge gaps in DRRE programs. The following provides a summary of the methodology used to develop the idea proposed in this work:

(1) Survey of CBRNe events and their physiological consequences, both short and long term, on children aged 0 to 18.

(2) Review of pedagogical literature to identify effective learning methods and determine their applications for interactive educational programs in emergency preparedness.

(3) Review of 30 case studies to conduct a critical assessment of existing DRRE initiatives.

(4) Identification of crucial elements for the proposed design of an age appropriate CBRNe curriculum for children.

3. RESULTS

3.1 CBRNe incidents and their effects on children and adolescents

First, the authors found it necessary to categorize CBRNe incidents into three main types. This categorization enabled a systematic evaluation of the findings regarding both short and long-term physical and psychosocial consequences on children affected by CBRNe incidents.

Incidental: refers to CBRNe disasters which have occurred through natural origin, such as epidemics or pandemics, or as the cascading effect of another (non-CBRNe) emergency.

Accidental: refers to CBRNe incidents caused by human error, resulting in the accidental or unintentional release or dispersal of a hazardous substance or agent.

Intentional: refers to any CBRNe incident in which harm to the general population or a subset of individuals is intentionally caused by a person or group of persons.

To establish the potential necessity and usefulness in designing an interactive children's CBRNe educational tool, extensive desk research was conducted on the consequences of CBRNe incidents involving children throughout the 20th and 21st centuries. The study compiled information on a range of events, such as the infamous industrial accidents which occurred in Seveso (1976) and Bhopal (1984), intentional biological outbreaks involving salmonella (1984) and anthrax (2001) in the United States, radiological and nuclear accidents such as Chernobyl (1986) and Goiana (1987), and explosive incidents targeting children and communities throughout the Middle East (early-mid 2000s). The results of this study greatly underlined the negative effects of CBRNe disasters on children. The following summary provides a brief outline of the major physiological and psychological impacts caused by the incidents reviewed in this study. The results of this desk research were fundamental in identifying existing gaps in social awareness and community preparedness against emergencies.

Chemical (Accident): Seveso, Italy 1976 [9].

In 1976 an accidental chemical explosion in Seveso, Italy exposed residents of the area to high levels of 2,3,7,8-Tetrochlorodibenzodioxin (TCDD), or Dioxin. As a result, 19 children were admitted to the hospital with skin lesions. Of the nearly 200 cases of chloracne, most were children under the age of 15. Subsequent studies found additional effects to include dysfunctional liver, impaired immune system, and defective dental development. Children aged 0 to 14 years from the greatest exposure area exhibited higher lymphocyte values, indicating dysregulated cellular immunity. A study found that males who were between the ages of 1 and 9 years old at the time of the accident exhibited lower fertility values and increased hormone levels after growth. Another study revealed that Dioxin levels were higher in children, specifically aged 13 or younger. Women, including young females, experienced greater medical repercussions compared to males, with significantly increased risk for developing irregular menstruation cycles, endometriosis, early menopause, breast cancer, diabetes, decreased bone health, fertility complications, and thyroid problems. Females under the age of 12 exhibited an increased risk of developing metabolic syndrome. The study also revealed that the half-life of Dioxin in Seveso residents was found to be 7.1 years for those over 10 years old, 5.2 years for children between 6 and 10 years old, and 4.3 years for children under 5. Therefore, children exposed to Dioxin at the pre-pubescent age were subjected to the greatest developmental repercussions during their critical years of growth.

Biological (Incident): COVID-19 Global Pandemic, 2020-2023 [10-14].

On March 11, 2020, the World Health Organization officially declared COVID-19 a global pandemic. The outbreak was caused by the incontrollable spread of the Sars-CoV-2 virus. The virus presented an increased risk of infection, health complications, and fatality for children with pre-existing conditions, such as congenital heart defects, obesity, asthma, immunodeficiency, chronic respiratory diseases, and sickle cell disease. The development of diabetes after infection was also a growing concern among children and adolescents. In some cases, children who recovered from COVID-19 developed a rare condition known as Multisystem Inflammatory Syndrome in Children (MIS-C), which can affect vital organs, including the brain, heart, lungs, and gastrointestinal tract. The Sars-CoV-2 pandemic also resulted in widespread psychosocial and educational deficiencies leading to increased concern as studies continue to be conducted on childhood development post-pandemic.

Radiological (Accident): Goiana, Brazil 1987 [15].

In 1987, radiological contamination from a Cesium-137 source occurred accidentally in Goiana, Brazil. The contamination resulted after the Istituto Goiano de Radioterapia, a private radiation therapy institute, changed locations, leaving behind a cobalt-60 teletherapy unit, and failing to declare this to the relevant authorities for proper disposal. The unit, which had already been damaged during a partial demolition of the building, was later discovered by citizens, who entered the premises and dismantled the unit in an attempt to sell pieces of it to a junkyard. This process caused it to rupture and subsequently resulted in both external and internal contamination of several individuals. Further environmental and human contamination occurred, as local

citizens, including children, continued to be exposed to the source, whose glow-in-the-dark blue powder fascinated them. As a result of exposure, decontamination of citizens and medical countermeasures were enacted. Consequently, Prussian Blue was administered to 46 people, of whom 13 were children. Four individuals died as a result of direct exposure. Subsequent studies found that over 112,000 people were affected through environmental contamination.

Nuclear (Intentional): Hiroshima & Nagasaki, Japan 1945 [16-19].

In 1945, during World War II, the United States of America intentionally released two atomic bombs on the Japanese cities of Hiroshima and Nagasaki, causing devastating effects to the civilian population of these two cities. The Radiation Effects Research Foundation estimates that 46% of victims from the atomic bombings experienced greater attributable risk (AR) for developing leukemia. Among this percentage, children were more susceptible to this risk than adults. According to the International Committee of the Red Cross (ICRC), childhood survivors were at high risk for developing multiple types of cancers because of stem cell damage caused by extensive radiation exposure. Additionally, individuals exposed to radiation from the atomic bombings while in utero exhibited birth defects such as small head size, mental disability, and physical growth impairments. Studies conducted by the Atomic Bomb Casualty Commission found that there were statistically significant impairments in both height and weight development in children exposed to radiation either in utero or at an early age (0-5 years). Furthermore, children who survived the bombing experienced substantial post-traumatic stress disorder (PTSD), depression, and radiation fear, which continued to affect them throughout their entire lives.

Explosives (Intentional): Yemen, 2015-2021 [20, 21].

Between 2015 and 2021 numerous and repeated attacks on schools were reported in Yemen as part of ongoing armed conflict in the nation. These attacks included air strikes, exchange of fire, planted land mines, and shells. An estimated 50 children were killed or injured by these attacks in the city of Taiz between January and March 2021. Around 200 children were killed in Taiz from 2018 to 2019. In the city of Lahj, one-third of civilian casualties from 2018 to 2019 were children. These attacks affected both the physical and psychological wellbeing of Yemeni children. Reports indicate that children in these situations risked their lives everyday by walking over land mines to get to school, many witnessed their classmates become injured, or were inside their schools while under explosive attacks. Studies demonstrated that 79% of the children in one Yemen city (Sana'a) developed PTSD symptoms. This is only one of many recent examples around the world, where the use of explosive devices in armed national conflicts and violent civil wars has caused significant detrimental effects to the psychological and physical wellbeing of children.

3.2 Pedagogical teaching methods and the benefits of emergency preparedness education

After verifying sufficient evidence on the prevalence of CBRNe emergencies involving children and their damaging effects, a comparative analysis was conducted on pedagogical learning theories to identify potentially effective teaching methods in the design of a CBRNe educational platform. There are several learning theories which address distinct learning needs and target specific educational or psychological outcomes: cognitive learning theory, behavioral learning theory, constructivism learning theory, humanism learning theory, connectivism learning theory, transformative learning theory, social learning theory, and experiential learning theory. A comparative review was conducted to identify which of these methods employs the best approach for effective development of a CBRNe curriculum.

3.2.1 Comparative review of common pedagogical learning theories

A comparative review of the main pedagogical theories highlighted the significance of selecting the appropriate methods to enhance learning, increase cognitive and psychological development, and transform individual behaviors within social environments. Some of these theories, such as cognitive and behavioral learning, place a strong focus on human interaction with their environment and social constructs, utilizing teaching activities designed specifically for psychotherapeutic therapies [22, 23]. Others, such as constructivism, humanism, and connectivism learning theories, highlight the process in which personal experiences, environments, and human interactions influence learning, thus developing into individual knowledge and future behaviors [23-26]. Other theories focus on specific age groups or types of students. For example, transformative learning theory is typically used to target young and older adults through the belief that experiences can shape future thinking [27]. Social learning theory targets younger students through which learning is shaped by observation of others' actions and behaviors [28]. The final theory, experiential learning, operates on the belief that individuals learn through action. In comparison to other theories, experiential learning helps individuals to acquire knowledge through experimentation and subsequently apply it to real-world experiences. This hands-on approach fosters the most effective techniques for knowledge acquisition and retention for use within the field of CBRNe education.

3.2.2 Identification of Kolb's experiential learning theory for CBRNe educational applications

As seen in Figure 1, Kolb viewed learning as a four-stage cycle: concrete experience (CE), reflective observation (RO), abstract conceptualization (AC), and active experimentation (AE).

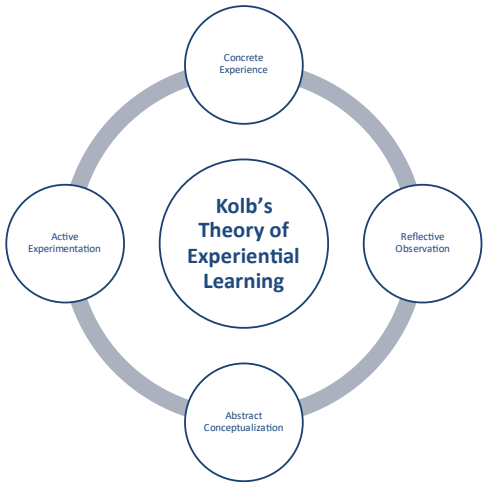

Figure 1. Kolb's cycle of experiential learning [29]

Each of these stages provides the foundational skills, observations, and ideas with which to develop the successive

stage of the learning process [30]. Learning involves active engagement, by which the student acquires knowledge through the transformation of experiences [30]. Experiential learning allows learners to create tangible connections between theories and real-world examples. Through action-based, or engaged learning, students develop vital life skills. Based on Kolb's theories, experiential learning theory is widely applied in childhood and adolescent learning. Consequently, these methods are used for a range of age groups to achieve various educational objectives, including self-efficacy, social skills, empathy and behavioral balance, self-perception, and civic responsibility, among many others [30, 31]. Research suggests that experiential learning methods present significant educational advantages for learners of all ages. These outcomes extend beyond achieving academic goals, to include the development of psychosocial, interpersonal, and intrapersonal skills [31].

Although there are benefits to each of the pedagogical theories defined in section 3.2.1, experiential learning has been proven as an effective method when applied to DRRE programs. Successful DRRE curricula employ competency-based, interactive, and action-oriented learning activities. In effective DRRE programs, students formulate knowledge, opinions, and feelings about disasters, the environment, and the damaging effects of hazards, through a blend of teaching mechanisms. This theory was then tested to determine the prevalence and use of experiential learning methods in existing DRRE programs aimed at increasing childhood awareness about natural hazards.

3.2.3 Pedagogical approaches to engaged learning

Following Kolb's framework, engaged learning can be further subdivided into six methods, as demonstrated in Table 1. These subdivisions encompass detailed teaching strategies which foster increased knowledge acquisition and strengthen learning outcomes. Interactive learning involves an engaged approach, in which students are provided with a mix of task-based activities, inquiry activities, project-based activities and collaborative work. With affective learning styles, students learn to understand concepts by recalling their own emotions or learning to understand the emotions and experiences of others. Inquiry learning involves internet-based tasks. Surrogate experiential learning methods include learning experiences through playing or through artistic creation and expression. One example of pedagogical activities pertaining to experiential learning methods is simulation gaming. Through field experiential learning, students obtain knowledge of a concept in a visual manner, by applying theory to real-world experiences. Finally, in action learning, students are tasked with acting on the knowledge they have acquired and in promoting awareness to the public on a specific issue. [31].

3.2.4 Benefits of digital technology in achieving learning outcomes

According to a study conducted in the United States in 2016 on the extent and purpose of technology use in American classrooms, there are five main roles that technology plays in education: (1) technology improves access, (2) technology enhances communication and feedback, (3) technology restructures teacher time, (4) technology extends purpose and audience for student work, and (5) technology shifts teacher and student roles [32]. For the purposes of this research, focus was only placed on those which directly influence student learning outcomes.

Table 1. Examples of engaged learning styles and activities [33]

Learning Type	Examples
Interactive Learning	• Brainstorming • Group discussions • Multi-media presentations
Affective Learning	• Sharing feelings about threats & disasters • Empathetic exercises based on disaster experiences
Inquiry Learning	• Team case study research & analysis • Internet enquiries • Project work
Surrogate Experiential Learning	• Filmmaking • Board games • Role plays • Dramas • Simulation gaming • School assemblies
Field Experiential Learning	• Field trips • Hazard mapping • Vulnerability assessment • Reviewing emergency plans • Interviewing local community members on disaster memories
Action Learning	• Raising community awareness • Developing risk maps and risk reduction plans • Poster campaigns • Street theatre • Risk reduction campaigns

Technology improves access to information and increases students' sense of responsibility in the learning process. Through technology, schools can provide students with information and resources beyond the textbook. Technology improves how activities can be experienced in correspondence with individual capabilities. For example, computer games enable action or selection review and exercise repetition to increase confidence with the subject matter [32].

Technology enhances communication and feedback by encouraging greater collaboration through group work. Students and teachers can communicate via various forms of media, easing the facilitation of project-based tasks and increasing methods of interaction and feedback. This also contributes to the development of leadership skills as well as collaborative learning [32].

Technology extends purpose and audience for student work by enabling information sharing and exchange and enhancing critical thinking skills development. With technology, learning extends beyond the classroom to include virtual field trips, online research, and broadens opportunities for student engagement [32].

In this way, technology works to complement traditional classroom-based learning by enhancing interaction and participation and increasing learning outcomes during the critical years of cognitive development.

3.2.5 Aims of disaster risk reduction education programs

Disaster risk assessment is calculated by recognizing the potential for a hazardous situation to occur and understanding

the vulnerability and probability of exposure of a specific area or population [34]. Additional factors which influence disaster risk include a community's knowledge and preparedness, its ability to respond effectively to a disaster, and its capabilities for successful recovery. In the contexts of both natural disasters and CBRNe emergencies, the calculation of disaster risk is widely recognized as the following equation [34]:

$$Risk = Hazard \times Exposure \times Vulnerability$$

The ability to quantify the disaster risk of vulnerable populations enables for preemptive action aimed at significantly reducing the devastation caused by probable emergencies in those communities. DRRE is the educational approach which has been adopted by many nations around the globe in response to this quantification of risk and is aimed at increasing the emergency preparedness and resilience of communities through the acquisition of useful knowledge. In many cases, these educational programs are included within the nation's school curriculum and are also referred to as school-based disaster risk reduction (SBDRR) education [33].

As natural and man-made disasters and technological threats continue to increase, research has found that preparing communities for specific emergencies is a vital step towards building resilience and reducing communities' vulnerability. Studies suggest that a greater number of injuries or fatalities due to emergency situations could be prevented by educating citizens on disaster preparedness and training response professionals in risk management [8, 35]. The benefits of learning emergency preparedness have been explored from three main target groups: (1) vulnerable citizens, (2) first responders, and (3) secondary responders. The terminology, 'vulnerable citizens', refers to members of the general public who are at greater risk of encountering harm or of experiencing greater suffering during a disaster. This concept applies to a wide range of circumstances, including pregnant women, children, the elderly, and individuals with disabilities. 'First responder' is the term used to indicate any civil service, military, or medical professional involved in the protection of citizens and in any phase of the response process during an emergency. The third target group, 'secondary responder' refers to civilian individuals who hold a higher responsibility in caring for the general public and especially any vulnerable citizens during an emergency, and who may be directly involved in the management or decision-making process of disaster response efforts. This includes teachers, taxi drivers, local authorities, governing officials, and policy makers. There are different methods of education and training modes required for each group due to differing factors such as age, role in the response process, level of authority, and level of prior knowledge. In all cases, studies indicate that any level of preparation or education on disaster prevention, recognition, and response is more beneficial than receiving no prior information or training [35].

3.3 Case studies: Analysis of disaster risk reduction education programs

A comprehensive review and analysis of 30 countries was performed to determine the scope of DRRE programs worldwide. The goal was to examine if and how potential CBRNe concepts and topics have been implemented in existing programs. The following elements were evaluated: type of instruction style used, type of emergency scenarios introduced, educational exercises or activities employed, country and language of implementation, and status as either a mandatory school program, optional educational materials, or a temporary pilot program for testing purposes. Results of this review demonstrated that while they are each unique to the needs and capabilities of the individual nation, many of these programs include some type of engaged learning activities, therefore highlighting its importance as an effective pedagogical method in disaster risk education.

To offer a brief outline of the differences and similarities of the 30 international DRRE programs evaluated, Table 2 highlights one example from each inhabited continent.

Table 2. Examples from case studies of DRRE programs [36]

Country	Emergencies Taught	Exercises/Activities
Republic of South Korea (Asia)	• Sinking cruise ship • Burning move theater • Earthquake evacuation	• Virtual simulations
New Zealand (Oceania)	• Earthquakes • Floods • Landslides • Storms • Tsunamis • Volcanoes • Pandemics • Fires • Droughts • Criminal acts & terrorism • Animal & plant pests and diseases • Hazardous substances	• Coloring pages • Videos • Factsheets • Videogames • Checklists • Weather forecasts • Educational DVDs • Presentations • Downloadable emergency stories • Information documents
Russian Federation (Europe)	• Natural hazards • Road safety • Conflicts • Terrorism • Fires • Technological hazards	• Presentations • Videogames • Board games • Internet searches • Role plays • Group discussions • Advocacy events

		• Art exhibitions • School competitions
Arab Republic of Egypt (Africa)	• Earthquakes • Fires • Floods • Desertification • Road and railway accidents • Volcanoes • Deforestation • Air pollution • Hurricanes • Conflicts & war	• Open discussions • Internet searches • Evacuation simulations
United States of America (North America)	• Earthquakes • Floods • Hurricanes • Tsunamis • Volcanoes • Wildfires • Winter weather	• Videogames • Coloring pages • Educational videos • Board games • Discussions • Checklists • Webinars • Workshops • Activity books • Fact sheets • Prep talks • Trivia
Republic of Costa Rica	• Tornadoes • Tsunamis • Floods • Earthquakes • Volcanoes • Landslides • Electrical storms • Technological threats	• Awareness campaigns • Drawings • Written communications • Songs • Risk and evacuation planning/mapping • Mural drawings • Online games • Quizzes

3.3.1 Case study #1: The Republic of Korea [36, 37]

Between 2018 and 2019, the Republic of Korea National Red Cross (KNRC) and the Asia Pacific Disaster Resilience Centre (APDRC) hosted an experimental Virtual Reality Disaster Training to deliver emergency preparedness simulations to the general public. The aim of this VR disaster resilience training is to train the public on general emergency situations and generate awareness on these issues. VR was chosen as the method of delivery for this training due to studies which have proven the effectiveness of action-based learning. The target audience for this training is any individual between the ages of 13 and 60. This program has also been distributed to schools. And offers three virtual scenarios, a sinking cruise ship, a burning movie theater, and an earthquake evacuation. The platform has also been distributed to other Asian nations including the Philippines, Nepal, Mongolia, Indonesia, Vietnam, Singapore, and Thailand.

3.3.2 Case study #2: New Zealand [38]

What's the Plan, Stan? is a free resource that was developed in New Zealand to support schools and parents in teaching children about emergencies. This program covers a wide range of natural disasters and potential hazards such as earthquakes, floods, landslides, storms, tsunamis, volcanoes, fires, droughts, pandemics, terrorism, animal and plant diseases, and toxic or explosive chemicals. *What's the Plan, Stan?* guides teachers in designing an emergency education curriculum that fosters the development of key competencies and skills to confront natural disasters and other risks. The curriculum is divided into two levels which target school students from years 1 to 3 and 4 to 8. Lessons involve teaching children about past emergencies in New Zealand and the science behind natural disasters, as well as how to recognize and react to potential dangers. *What's the Plan, Stan?* offers a varied range of activities, including coloring pages, thinking maps, quizzes, preparation checklists, YouTube videos, and more, which provide children with visual and interactive materials to learn emergency preparedness skills. There are also a separate set of resources for varying age levels available in the Māori language to teach the indigenous children of New Zealand about emergency safety.

3.3.3 Case study #3: The Russian Federation [33]

In accordance with the Hyogo Framework for Action (HFA), Russia implemented a federal program called *Risk Reduction and Mitigation for Natural and Technological Disasters in the Russian Federation by 2015.* This program was the third phase of development, which began in 2000, under the direction of both the Ministry of Enlightenment (formerly the Ministry of Education) and the Ministry of Emergency Situations (also known as EMERCOM - the Ministry of Civil Defence, Emergency Situations, and Elimination of Consequences of Natural Disasters). This mandatory school curriculum for all 11 grades (both primary and secondary schools) includes the subject *Basics of Life Security*. This subject involves disaster risk reduction training comprised of natural hazards, technological hazards, road safety, conflicts, and terrorism. Students are engaged through a variety of lesson types, including cartoons, videogames, board games, role plays, group discussions, excursions, videos, and in-class and home-based exercises. Students are assessed on their knowledge numerous times throughout the school year via examinations

or games. The many goals of this DRRE curriculum include (but are not limited to) knowledge of risks, the different types and consequences of disasters, first aid, civic duty, self-protection, responsiveness and how to make good choices in a disaster, and how to analyze and assess situations.

3.3.4 Case study #4: The Arab Republic of Egypt [33]

Under the HFA, the Egyptian government conducted a national progress report to determine the state of its DRRE program. SBDRR is included in the national curriculum at both the primary and secondary levels under the Ministry of Education. As part of the SBDRR, schools conduct evacuation drills for various simulated disasters at least three times per school year. At the primary school level, DRRE subjects that are taught to students include safety in the case of earthquakes or volcanoes, reacting to crises, reducing environmental risks, and general knowledge of hazards such as air pollution, deforestation, floods, droughts, hurricanes, and more. Students are assessed on their knowledge through a national testing system. Challenges to the improvement of the existing system include a lack of teacher training and resources. Consequently, the DRRE program remains to be taught using a traditional classroom lecture-based approach and no significant experiential learning methods have been implemented in the teaching program to date. Similarly, lack of teacher training has also resulted in a lack of consistency and frequency with which DRRE lessons are integrated into the regular school curriculum. Therefore, there is a prevalent weakness in the amount and type of education that Egyptian students are receiving in these subject areas. Lastly, the Egyptian SBDRR lacks a coherent institutionalized evaluation system, creating additional challenges in student learning assessment and the evaluation of the curriculum's effectiveness.

3.3.5 Case study #5: The United States of America [39]

The United States of America has an extensive set of resources for parents, children, and educators to teach children about disaster preparedness. These resources were developed by the Federal Emergency Management Agency (FEMA). DRRE is not mandatory in schools in the U.S., however, these resources are available to encourage both parents and teachers to help prepare kids for natural disasters and other emergencies. The Ready Kids curriculum is divided into four categories: kids, teens, families, and educators. It involves a mix of games, facts, exercises, and other tools for teaching children about disaster. Many of the resources are available in multiple languages, including English, Spanish, Chinese, Vietnamese, and Korean. The curriculum covers a variety of natural disasters such as earthquakes, floods, hurricanes, tsunamis, volcanoes, wildfires, and winter storms. Teachers are able to download lesson plans and teaching guides according to different grade levels. These lesson guides include age-based learning outcomes, activities to do with students, words to know, and provide additional resources for further teaching opportunities.

3.3.6 Case study #6: The Republic of Costa Rica [33]

The SBDRR program in Costa Rica has been in development since the 1980s. In 1987, the 'Educational Programme for Emergencies' was established by the Ministry of Education. The main goal of this program was to develop didactic materials for teachers to educate students on first aid and evacuation plans in case of an earthquake or fire. Costa Rica's disaster education was further developed in 1991 when it was integrated into the curricula for science and social studies at the primary school level and included in secondary school subjects beginning in 1993. The SBDRR curriculum in Costa Rica is comprised of a range of interactive and action-oriented activities, including awareness campaigns, risk mapping, artistic contests, and designing evacuation plans. In seeking to implement a national plan under the HFA, Costa Rica created the PLANNERYD (National Plan for Disaster Risk Reduction Education). Curriculum development was included among its goals and a 2007 report indicated that the country had both increased participation and improved teacher training. The activities and subjects offered in the Costa Rican SBDRR program include mapping areas vulnerable to floods or landslides, creating a vocabulary list of words on disaster prevention, development of an earthquake risk management plan, analysis of media coverage on disasters, and a mapping of the community perception of risk. Despite the continued importance placed on the implementation of an SBDRR curriculum in the Costa Rican school system, little evidence has been found indicating adequate allocation of resources and commitment to the preparation and training of teachers. Additionally, there is no available information on student assessments or concrete data regarding the achievement of learning outcomes through this SBDRR education program.

3.4 Developing a child-friendly CBRNe preparedness curriculum

Finally, an examination of best practices in pedagogy and findings from the case studies were used to propose potential methods for the development of engaging, interactive, and age-appropriate curricula to introduce fundamental elements of CBRNe awareness and preparedness to children ranging from ages 3 to 17 years old. Based upon the sensitive nature of CBRNe concepts, it was necessary to divide the curricula into three age brackets, enabling a clear identification of activities and learning materials, following a visibly defined progression from basic introductory elements for younger students to more complex and intricate concepts as the children become older. The learning style selected for each age bracket also reflects considerations related to crucial pedagogical aspects, such as the previous knowledge acquired, the level of engagement or interaction, the number and complexity of tasks involved, and the time required to complete a specific activity.

3.4.1 Ages 3-6: Active participation activities [40]

For the youngest age bracket, children aged 3 to 6 years old, CBRNe education could be introduced through simple, short activities that require active physical participation in groups or as a whole class. Examples of this are role plays, dramas, memory games, or activities whose objectives are to understand and recognize the symbols associated with certain types of dangers or hazards, how to recognize authority figures or first responders, etc.

3.4.2 Ages 7-13: Screen-based learning exercises [40]

The second age bracket involves children aged 7 to 13 years old. For these age groups, interactive screen-based learning exercises could be used to build upon ideas and concepts learned at an earlier age, and visually introduce them to new elements related to CBRNe safety. Examples of this include interactive serious games (via a tablet or desktop), simulations involving quizzes, group tasks, and critical thinking exercises,

with clear goals and incentives such as rewards for successfully completing levels. Some topics could include learning the dangerous effects of mixing chemicals, understanding how hazardous agents are safely transported, recognizing sufficient ventilation systems, etc. Furthermore, children aged 11 and 12 could receive a basic introduction to simple Augmented Reality (AR) or Virtual Reality (VR) exercises either for individual or group-based work, enabling them to receive a strategically paced introduction to the technology which will be utilized as they progress academically to the next CBRNe curriculum age bracket (ages 14-17).

3.4.3 Ages 14-17: Fully immersive virtual reality scenarios [40]

This age bracket involves a fully immersive VR CBRNe learning curriculum for adolescents aged 14 to 17 years old. The activities and learning materials of this curriculum should be based upon a continued progression from the units offered throughout the previous stages of learning. A fully immersive VR curriculum would be comprised of realistic and immersive simulations presenting more complex emergency scenarios, within an acceptable framework for the target audience. These could involve developing skills in recognizing various contamination symptoms, how to assist others who have been exposed, and whether "shelter in place" or evacuation is the appropriate response. These VR scenarios could involve both single player tasks or multiplayer exercises to increase engagement and productivity.

4. DISCUSSION

There are numerous methods which have been studied from a psychological and pedagogical perspective to determine best practices in early childhood and adolescent education. This research has established that experiential learning is considered among the more effective means of teaching children and has many significant educational advantages. Experiential learning, whether in the form of serious games, action-based activities, group work, or VR simulations, engages all facets of cognitive thinking and creates a holistic learning experience for the student. These qualities, applied to disaster preparedness education, improve the lessons learned and increase retention of vital and life-saving knowledge. Important aspects of experiential learning exercises include the promotion of critical thinking skills, the facilitation of collaborative environments, and the development of fundamental life skills such as situational awareness, civic responsibility, self-reflection, and communication. In disaster preparedness, effective learning should be facilitated through problem-based, action-based, or task-based activities, during which children are not only physically engaged in the learning experience but are also provided with the opportunity to develop thoughts, emotions, and self-efficacy during an exercise. Successful emergency preparedness education offers the opportunity for feedback, evaluation, reflection, and inquiry, in which students can understand mistakes, question actions or decisions, and develop personal opinions about hazards and response mechanisms. Consequently, by fostering the development of these skills and increasing the way knowledge is acquired and remembered, experiential learning improves children's ability to recognize, react, or even avert disaster entirely in the event of a real emergency.

The case studies analyzed for the purposes of this research provided a brief insight into the disaster preparedness curricula offered in 30 countries around the world. Each of these countries experiences different types of risk according to geographical location, political structure, demographic populations, economic stability, access to resources, and potential for emergency recovery. Consequently, each has taken a significantly different approach to introducing hazards and preparedness to their children to increase national resilience. The Korean approach has begun to integrate innovative digital technologies by designing a VR platform to teach a few incident scenarios to the general public. In New Zealand, a more traditional and limited approach has been implemented by providing online resources to teachers. Although this system has not been widely adopted, New Zealand has demonstrated a notably inclusive methodology by adapting specific resources for their indigenous groups and providing them in the Māori language. Russia has established a functional integration of emergency preparedness with the inclusion of DRRE subjects and evaluations in the national school curriculum. Egypt has also included a traditional classroom-based approach to DRRE in the national school system. However, with restricted resources and little teacher training, there is limited evidence of its efficacy and genuine implementation in schools around the country. The United States of America has established an extensive collection of resources for teachers, parents, and children to educate and raise awareness about natural disasters. Although it is not a mandatory part of the school curriculum, its creation by an agency of the federal government demonstrates the nation's commitment to allocating necessary resources and improving disaster education. Finally, Costa Rica's DRRE system has been in development since the 1980s. Although they have made continuous strides to strengthen their national curriculum over the years, there is still much work to be done in the efficient training of teachers and appropriate allocation of resources to improve the curriculum and its overall effectiveness in teaching children about disasters [32, 36–39].

In all the case studies evaluated, there are a few lessons which can be learned from the strengths and weaknesses of these already-existing systems. Based on these, the following is a list of relevant recommendations to improve the effectiveness of current and future disaster education programs:

(1) Better teacher training is needed. Regardless of the extent to which resources and funding are available in any country, a DRRE curriculum has little effect without proper teacher training and implementation of appropriate pedagogical practices.

(2) There is a global need to increase the allocation of resources and continue to encourage national commitment to DRRE by including it as a mandatory part of every national school curriculum.

(3) Some countries still utilize traditional classroom lecture-based approaches or limited engaging activities in their DRRE curricula. There is a need to improve the knowledge and understanding of effective pedagogical styles and increase their implementation to efficiently educate children on these important subjects.

(4) A standardized approach for the national assessment of the DRRE curriculum's effectiveness should be highly encouraged and utilized by each country.

(5) All countries should be held accountable for implementing an effective evaluation and feedback system of their DRRE program to ensure sustainability and track its

continued success.

Following extensive research on the current DRRE programs available around the world, it is evident that there is a gap in the subject matter offered to students, especially in areas prone to CBRNe risks. Globally, there is a tendency to develop and focus solely on CBRNe education and training programs for the training of first responders or CBRNe operators. At the school level, preparedness and response is only provided to teachers, parents, and school staff on how to get children to safety during natural disasters, evacuations, or in active shooter situations. However, there has been little evidence that CBRNe subjects are being considered or addressed with schools and communities to increase public knowledge of these hazards, despite the increased risk of these types of emergencies on an international level. Therefore, there is a heightened need to create awareness of CBRNe issues, and specifically, their increased effects on children, to promote its universal inclusion in education systems. To do so signifies the need to open dialogue and increase knowledge and communication about the necessity and potential benefits of introducing basic CBRNe concepts to children.

5. CONCLUSIONS

Whether incidental, intentional, or accidental, a CBRNe event can cause damaging effects on people, animals, and the environment. Extensive research has demonstrated that there is an evident gap in the subject matter offered to students through DRRE programs. Considering various types of pedagogy, experiential learning methods could be the most effective solution for teaching emergency preparedness to children. The aim of this paper is to offer an innovative idea which can be individually tailored by local, regional, or national authorities according to specific needs and capabilities. As described in the discussion part of this paper, the pedagogical aspects, specifically in dealing with such a delicate subject such as CBRNe, would need to be developed by professionals in the field of education upon intense study. The development of this idea is also dependent on other factors such as funding, teacher training on CBRNe response, and policy implementation (through which such a program would be made a standardized part of a school curriculum). For this reason, only a few brief examples have been provided to give readers an idea of the potential that this idea has for future development. This research proposes the design and development of an interactive, immersive, and engaging CBRNe curriculum, divided into three age brackets (1) ages 3-6, (2) ages 7-13, and (3) ages 14-17, which would progressively and systematically teach children what to expect, increase their preparedness, and improve overall community resilience in the face of a CBRNe disaster. The advantages of this idea are that children and communities will be more prepared to recognize a CBRNe hazard and will have the knowledge to react in a way which may prevent unnecessary injury, long-term health conditions, or even death. The program must first be evaluated and developed by pedagogical experts, and then subjected to individual testing in countries willing to introduce CBRNe concepts to children.

It is important to note that there were limitations in conducting this research, for which it is critical that additional factors be heavily studied and explored before fully implementing a CBRNe educational curriculum for children. These include the need to further research:

- The potential psychological effects of introducing CBRNe concepts to children, especially at an early age, taking into consideration that children are highly susceptible to emotional trauma.
- How to ensure inclusivity of an interactive CBRNe educational program for children with physical or cognitive disabilities (i.e., blind, deaf, neurodiverse, etc.).
- The program has not yet been evaluated and developed by educational experts. Therefore, there is the need for targeted expertise to design "safe" CBRNe learning modules for children, including the potential need to integrate traditional, or lecture-based, teaching styles as well as offer recapitulation sessions to reinforce student learning.
- The need for teachers and school educators to receive specialized training on CBRNe hazards, risks, and effective protection and response measures.
- The need for experts in VR software programming with specific knowledge pertaining to the development of CBRNe-related training/educational scenarios.
- Increased prioritization by policy makers and Nation-States to secure sufficient funding, allocate resources, and explore language adaptation of a developed CBRNe curriculum.

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