sustainability

MDPI

Article

Earthquake Vulnerability Reduction by Building a Robust Social-Emotional Preparedness Program

Shira Daskal [1,*], Adar Ben-Eliyahu [2], Gal Levy [2], Yakov Ben-Haim [3] and Ronnen Avny [4]

[1] The Natural Resources and Environmental Research Center (NRERC), University of Haifa, Haifa 3498838, Israel
[2] Faculty of Education, University of Haifa, Haifa 3498838, Israel; adarbe@edu.haifa.ac.il (A.B.-E.); gal_levy178@hotmail.com (G.L.)
[3] Faculty of Mechanical Engineering, Technion—Israel Institute of Technology, Haifa 3200003, Israel; yakov@technion.ac.il
[4] Institute for the Development of Enterprises, Corvinus University of Budapest, 1093 Budapest, Hungary; ronnen.avny@stud.uni-corvinus.hu
* Correspondence: shira.daskal@post.idc.ac.il

Abstract: Despite the progress made in understanding the characteristics of earthquakes, the predictions of earthquake activity are still inevitably very uncertain, mainly because of the highly complex nature of the earthquake process. The population's mental strength is of high importance not only to cope with an earthquake, but also to return quickly to functioning. Social-emotional preparedness for extreme adverse events and crises is a critical factor in the population's quick recovery and return to full functioning. In the present study, we apply a multi-disciplinary lens to extend the scope of earthquake preparedness to include social-emotional programs. The goal of this study is to develop a robust "no-regret" social-emotional preparedness program (SEPP) along with methodological tools for evaluating the SEPP robustness against uncertainty in different earthquake scenarios. The research methodology is twofold. First, we develop the SEPP based on social-emotional proxies-for-robustness, and second, we apply the info-gap decision theory (IGDT) methods to assess the robustness of the SEPP in the face of uncertainty in different earthquake scenarios. The findings indicate gaps between the level of robustness of the SEPP in different scenarios. A key conclusion that emerges from this study is the need for a robust SEPP to make a significant contribution to the population's ability to return to functioning. Such SEPP should be formulated to maximize the robustness against uncertainty in different scenarios, rather than the traditional planning based on a 'one size fits all' approach. Formulating a robust SEPP by analyzing the robustness of the SEPP against uncertainty will enable to make decisions immune to surprises. Ways to create or improve earthquake preparedness are suggested for policy and in-school application.

Keywords: earthquakes; info-gap decision theory (IGDT); robustness; social-emotional proxies for robustness; uncertainty

check for updates

Citation: Daskal, S.; Ben-Eliyahu, A.; Levy, G.; Ben-Haim, Y.; Avny, R. Earthquake Vulnerability Reduction by Building a Robust Social-Emotional Preparedness Program. *Sustainability* **2022**, *14*, 5763. https://doi.org/10.3390/su14105763

Academic Editor: Claudia Casapulla

Received: 23 February 2022
Accepted: 6 May 2022
Published: 10 May 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Earthquakes are one of the most destructive natural hazards and they can lead to severe economic, social, and environmental impacts. In the 20th century, earthquake disasters killed approximately 1.87 million people globally [1], with 801,629 deaths worldwide between 2000 to 2015 as reported by the United States Geological Survey (USGS) Earthquake Hazards Program research [2]. The economic effect of earthquakes is significant. For example, three major earthquakes in 2010–2011 in China [3], New Zealand [4], and Chile [2,5] caused approximately three hundred billion USD in damage, while the annualized earthquake loss estimated by FEMA is 6.1 billion USD per year [6,7]. A recent report of the OECD (2018) [7] estimates the global annual damage due to earthquakes as 34.5 billion USD, which is subject to increase within the near future due to rapid urbanization and

the accumulation of assets in seismic areas. An interesting outcome is that 86.7% of the population is affected by earthquakes in lower-middle and low-income countries [7].

It is not surprising that there has been a rising interest related to disaster relief operations focused on two central topics, operational logistics, including rescue operations, medical rescue support, and evacuation efforts [8–10], and preparedness to ensure resources for coping are available in advance of the disaster [11–14]. Even if these serve the physical needs of the first response, the social sustainability efforts of coping with a disaster are neglected within these models.

Social sustainability broadly refers to maintaining functioning and social relationships even during extreme and challenging circumstances such as an earthquake [15]. Current work seeks to improve social-emotional mechanisms to ensure durable social interactions [16].

Social-emotional preparedness (SEP) for extreme adverse events and crises is a critical factor in the ability of the population to recover and return to functioning after such events. Characteristics, such as good citizenship, solidarity, emotion regulation skills, interpersonal communication, conflict management, and personal strength, contribute to the population's ability to function, the willingness to comply with instructions, assist emergency and rescue services, and reduce crime and violence. All of these help to reduce secondary damage and shorten recovery time from the crisis. We propose that investing in SEP is a "no regret" strategy. The "no regret" strategy is a commonly used concept in emergency risk management. This approach is well known in changing climate-risk related strategies, which was introduced by the World Bank (2009) [17] and others as the best insurance policy because it improves society's generalized ability to cope with disasters, not simply to mitigate one potential disaster scenario that may or may not occur [18]. The no-regret concept is defined as having multiple objectives rather than having only one objective as usual (usually to maximize the expected payoff). The decision-maker wants to ensure that there are no regrets (or being regret-free) by having many alternative goals, even though the expected emergency may not appear [19,20].

Falling within this "no regret" strategy are social-emotional preparedness programs (SEPP), usually designed based on past occurrences of similar events. These past occurrences are inevitably different from future occurrences (which have not yet happened in reality), and therefore do not provide reliable planning in the face of the deep uncertainty that characterizes an extreme event such as a severe earthquake. Because catastrophic cases are characterized by deep uncertainty, preparedness programs based on the best assessment of these future scenarios (based on past events) are not reliable and are vulnerable to future surprises. Thus, the preparedness program should be designed so that the level of robustness in the face of uncertainty is high enough to meet critical requirements at the time of future occurrence. Related to this, as will be further elaborated on below, robustness refers to the ability to maintain the performance of critical requirements despite changing and unexpected circumstances [21].

Governments tend to focus on operational logistics, which are critical for recuperation [22,23]. However, we claim that more attention should be given to components that build an emotionally sturdy population because the population's mental strength is of high importance to cope with an earthquake as well as return to functioning quickly [24]. This notion that investment in strategies for well being in the face of diversity and challenging circumstances, or social sustainability, has become even more important as current COVID-19 findings point to the damage caused due to a lack of social-emotional capacities that has led to severe decrements in well-being for children and adults globally [25].

The current work considers SEPP for earthquakes by integrating the notion that there will be gaps when we prepare for future events based on past occurrences. From this perspective, we apply the lens of info-gap decision theory (IGDT) for a nuanced assessment of robustness against uncertainties in the event of an earthquake of different magnitudes. To do this, we develop an innovative and unique multidisciplinary methodology, which includes theoretical and practical aspects for constructing a SEPP that is highly robust in the face of uncertainty in the event of an extreme earthquake.

1.1. The Context of the Social-Emotional Program

To illustrate an application of the proposed multi-disciplinary methodology, we construct guidelines and an application example of SEPP in schools. Drawing on the Cohen-Harris Center Urban Resilience Program [24], we chose schools as they are ideal for pre- and post-trauma interventions because of the large number of civilians that are affected by the school directly, such as teachers, administrative and educational staff, and the children and adolescents that attend schools, and indirectly, such as the families of these children and staff. School programs reach a large number of civilians directly and even more so indirectly (e.g., parents of children or family members of staff) so that a structured program, by incorporating elements into daily school life, has many benefits with potential for far-reaching implications. Moreover, schools enable collaborative implementation by incorporating schools, municipalities, and emergency bodies.

The SEPP proposes no-regret actions intended to help cope and decrease the vulnerability of the population in crises, with a focus on earthquakes of large magnitudes. These are no-regret investments as they would have benefits even if the earthquake does not occur, as the implementation of these programs still can be used in other crisis situations, such as coping with a pandemic, war, or terror attacks, tornados, and even in every-day life.

To estimate how social-emotional aspects could be incorporated into earthquake preparedness, as a point of departure we drew on the Israeli National Steering Committee for Earthquake Preparedness (INSCEP) preparation framework for a devastating destructive earthquake event in Israel [26]. The INSCEP's plan includes a statistical model as the basis for calculating the expected level of damage caused by a catastrophic earthquake. The model is based on a Poisson function introduced by the US Applied Technology Council in 1985 [27]. This function may not correctly represent the case of earthquakes, as the Poisson distribution assumes independent events and precise knowledge of a fixed average rate over time, which are likely incorrect assumptions when it comes to geophysical processes that characterize the cause of earthquakes. This implies a gap between the best estimation based on the suggested model and the actual outcome of the catastrophic event. This is a knowledge gap, for which the event space is not structured in a probabilistic manner, and thus a probabilistic model will not yield a good enough indication for the robustness against uncertainty in the face of crucial requirements. To rectify this knowledge gap, we use the info-gap analysis that enables better estimation and planning.

1.2. The Context for Info-Gap Analysis

Info-gap decision theory (IGDT) proposes a non-probabilistic model of uncertainty and provides methods for evaluating the robustness of decisions in cases of unbounded non-probabilistic deep uncertainties [21,28–32]. The info-gap analysis, in this case, is aimed to determine the level of robustness-to-uncertainty of SEPP, to improve the functioning of the population in the face of earthquake scenarios as expressed in the INSCEP's model.

The analysis was performed for evaluating the strength of social-emotional proxies-for-robustness to earthquake uncertainty. The guiding principles of the preparedness program were: (1) Measures that can be implemented through existing resources and without the need for a significant budget investment. (2) Taking no-regret measures that are beneficial to the state and citizens even if a devastating earthquake does not occur. The no-regret SEPP was assessed in terms of the level of robustness to uncertainty in the case of a seismic level 9 earthquake and a seismic level 7 earthquake. The level of robustness was assessed qualitatively based on a set of social-emotional proxies for robustness, as further detailed in the paper.

In what follows, we present the consequences and effects of destructive earthquakes according to the INSCEP model, we discuss the importance of social-emotional preparedness, and we present the methodology and the application example of a SEPP.

2. Earthquake Consequences and Effects

Crises such as destructive earthquakes threaten our basic needs and well-being. In the case of a large-scale earthquake, the supply of basic resources such as food, water, and medicine may be delayed. Resources such as electricity and gas may also be limited or even null, as well as the logistic support to the areas affected by the earthquake [10,33].

In Israel, there has been almost no experience with destructive earthquakes in recent decades, and cases of earthquakes of magnitude 5 and above since the year 2000 are very few and most have occurred in non-populated areas [34].

However, the State of Israel is preparing for a scenario of a destructive earthquake and has set up an inter-ministerial committee, the INSCEP, to assess potential damage.

To this end, the INSCEP presents an estimation of the damage from earthquakes [20], to which we related in our research. In the current study, we concentrate on two scenarios defined by the level of damage and injury in reinforced concrete buildings, based on two seismic intensity levels: seismic intensity 7 and seismic intensity 9, as presented in Table 1. In the first two columns, the estimated level of damage is presented. The numbers in the last two columns of Table 1 are the percentages of buildings that suffer the level of damage identified in the first two columns. For example, at seismic intensity 7, 38% of the buildings will have minor damage, and 1% will have heavy damage, whereas in seismic intensity 9, 30% of the buildings will have minor damage and 4% will have heavy damage. The level of injury describes the percentage of casualties in the building (injured, killed), according to the level of damage to the building [26]. These estimates made by the INSCEP presume some specific locations of the earthquake center, relative to population centers. Different earthquake centers will yield different results, another source of uncertainty that the IGDT accommodates.

Table 1. Estimation by the INSCEP of the damage from earthquakes in reinforced concrete buildings.

Level of Damage	Level of Damage to the Building (%)	Minor Injury (%)	Moderate Injury (%)	Serious Injury/ Death (%)	Seismic Intensity 7 (%)	Seismic Intensity 9 (%)
None	0	-	-	-	49	14
Minor	0.5	-	-	-	38	30
Weak	5	0.033	0.0033	0.0011	8	24
Medium	20	3	0.03	0.01	2	16
Large	45	3	0.3	0.1	1.5	10
Heavy	80	30	3	1	1	4
Destruction	100	40	20	20	0.5	2

To consider the best SEPP for the range of earthquakes, with a focus on the seismic intensity of 9, we consider the recovery time based on the amount of damage. Table 2 presents the recovery time of crucial infrastructures, estimated based on the extent of the damage as defined by the INSCEP. For instance, the best estimate for recovery of the electric grid following an earthquake of seismic intensity 7 is 48 h, and two weeks following a seismic intensity 9. Clearly, coping with 48 h of electricity outage will elicit different responses than coping with two weeks of electricity outage, and similarly for other services.

Because we consider the damage and recovery time, one of the most important determinants of recovery is the extent to which people can implement recovery strategies. Of course, if one is unable to function due to shock, even the best of training in the infrastructure or medical field will not come to fruition. This suggests the importance of social-emotional preparedness. Below we begin with a further discussion of the importance of social-emotional preparedness. This is followed by a description of IGDT that provides a framework for defining and assessing robustness in the face of uncertainty.

Table 2. Estimation of minimal service level time. Source: An estimation from the Israeli emergency services.

Subject	Minor	Seismic Intensity 7	Seismic Intensity 9	Outcome
Electric Grid	Up to several hours	48 h	2 weeks	No electricity power—home, local governments, etc.
Water supply	No major downtime	48 h	2 weeks	Shortage of water supply, but alternatives exist (logistic centers for water supply)
Food Supply	No impact	No impact	2 weeks	
Banking	No impact	No impact	48 h	
Public media (TV, Radio)	No impact	No impact	24 h	Impact the public publication and accurate information delivery to the public
Personal communication (cellular phone, landline connection)	Minor impact	48 h	Up to one week	
Emergency communication	No impact	Minor impact	Up to one day	

3. The Importance of Social-Emotional Preparedness

The disarray caused by earthquakes leads to feelings of threat to one's safety causing stress, anxiety, and negative emotions that are likely to surface. It is, therefore, crucial to prepare civilians not just with basic survival skills, but also with skills for social-emotional coping with these challenges. Such skills contribute to the level of robustness in the face of uncertainty for coping to facilitate bouncing back to normalcy. Drawing from the literature on urban resilience [24], we focus on various investments that can be implemented within school programs in preparation for such catastrophic events to reduce their long-term impact. When such investments are assumed to be valuable irrespective of how future conditions evolve, they are termed as 'no-regret' options, in that even if the crisis does not transpire, there is value to their implementation. In this sense, building social-emotional preparedness is a no-regret investment in that it strengthens individuals and contributes to good citizenship, solidarity, interpersonal communication skills and enhances personal resources [35]. This becomes especially crucial for events that require a longer time for recovery.

Social-emotional learning has received much attention within school settings [36], so our proposal to incorporate the SEPP as part of earthquake preparedness is highly feasible and should be easy to implement. Within schools, social-emotional learning refers to the process through which one acquires and effectively applies the knowledge, attitudes, and skills necessary to understand and manage emotions, including setting and achieving positive goals, and establishing and maintaining positive relationships [37]. Similar to academic learning, social-emotional learning may be acquired through culturally and developmentally appropriate classroom instruction that focuses on building skills related to emotion recognition and management, taking the perspective of others, and handling of interpersonal communication [38].

In the case of earthquakes, we considered SEP as the population's ability to maintain functioning during the stressful experience of an earthquake, by taking actions to prepare and train the population in the face of a "may happen" catastrophe. This is especially critical for coping with destructive earthquakes during which infrastructure such as roads and buildings will be damaged. In such cases, what remains are the people themselves, and their ability to handle and cope with the situation and help each other. Therefore, the readiness of the population, as well as the training of individuals and groups in the population to perform various actions, is crucial. As schools have a statutory responsibility

to promote the well-being of students [39], we consider how schools may prepare children and youth.

This is a long-term no-regret investment because such programs shape future adults; an investment in minors reduces vulnerability in the long-term for the population at large. One of the challenges educators face is the limited resources and time, so they are taxed with prioritizing components of social-emotional learning, knowing that not all aspects will receive appropriate attention. The suggested framework for SEPP contains substantial attributes of robustness, which provide useful guidelines for practitioners as they sort through possible implementations of programs. To combine the range of multi-disciplinary perspectives, we draw on IGDT for evaluating the robustness of the SEPP at two seismic level earthquake scenarios, seismic level 9 and seismic level 7.

4. Methodology

In the present study, we apply a multi-disciplinary lens to extend the scope of earthquake preparedness to include a SEPP and we construct guidelines and an application example of the SEPP in schools.

To combine the range of multi-disciplinary perspectives we drew on IGDT, which considers uncertainties of events, and we implement methods for evaluating the robustness of the SEPP at two seismic level earthquake scenarios, seismic level 9 and seismic level 7. The evaluation was performed by a multi-disciplinary team with first-level operational experts, as well as a psychologist, an educator, and an environmental expert.

The IGDT analysis consisted of qualitative robustness analysis based on proxies-for-robustness, as detailed below. A schematic description of the methodological framework and stages is shown in Figure 1.

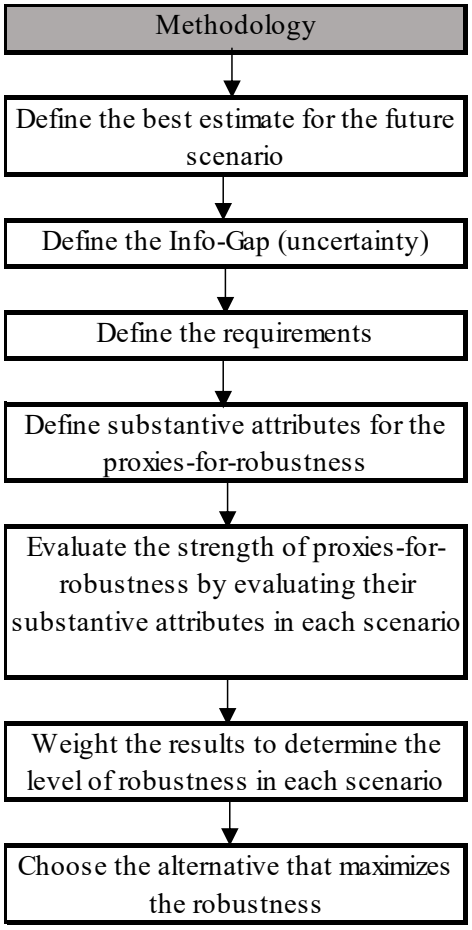

Figure 1. Schematic description of the methodological framework and stages.

During this evaluation process data from past events was taken into account, including lessons learned from emergency events, team members' own experience, and estimation from the emergency-related organization in Israel. Each member evaluated each of the six proxies, and when there were differences of opinion in assessing the strength of a proxy these disagreements were discussed until consensus was reached.

We based the SEPP on prior work investigating preparedness programs that include social-emotional components to identify the main and most important no-regret actions that can be implemented as school-based applications. Those actions were then sorted according to their characteristics and associated with social-emotional attributes. This framework provides a pragmatic approach to implementing such a program because educators may pick and choose which elements to include in the program. We drew on descriptions of social-emotional programs implemented in schools internationally to consider whether there should be different plans according to the severity of the seismic intensity. The robustness of the suggested program was qualitatively analyzed based on proxies for robustness. The proxies were assessed based on the strengths of the contribution of the substantial attributes of the proxies.

The estimation of minimal service level time (in Table 2) and the strength of the social-emotional proxies for robustness (in Table 3) were assessed by the Israeli emergency services. The strength of the social-emotional proxies for robustness was assessed on a scale of: 1—low; 2—medium; 3—high.

To illustrate the comparison between the overall level of robustness of the SEPP for both scenarios, seismic level 9 and seismic level 7 (based on the assessed strength of the proxies for robustness), we used the Radar chart analytical tool. Charts, such as Radar or Kiviat, enable multi-criteria benchmarking and the presentation of multiple performance indicators [40,41]. The area delimited by the polygon created by connecting the values of the proxies represents the level of robustness at each seismic level.

4.1. Robustness Analysis

The main decision support tool of IGDT is the robustness function [21,28–32,42,43]. Robustness is the attribute of satisfying critical performance requirements in the face of deep non-probabilistic uncertainty. The critical performance requirements are specified by what needs to be achieved for the outcome to be acceptable [31]. The robustness is assessed by answering the question of how wrong can our current understanding be while the outcome of our planning and preparation (despite our ignorance) will still be acceptable, or in other words, how immune are our decisions to surprises. A decision is highly robust if it remains acceptable throughout a relatively wide range of deviation of future reality from the original understanding. More robustness to uncertainty is better than less, so decision-makers should prefer the more robust decision over one with less robustness to uncertainty [31].

4.1.1. Quantitative Robustness Analysis

Sometimes, the robustness can be evaluated quantitatively [21,28,43,44]. In other cases, where quantitative analysis cannot be performed, the robustness may be assessed qualitatively [21,45]. The critical performance requirements are specified by what needs to be achieved for the outcome to be acceptable.

In the case of earthquakes, the population and their institutions are robust if they can expeditiously return to daily functioning, good citizenship, and basic educational and economical functionality, over any of a wide range of specific realizations of the earthquake. In the current study, the robustness is assessed by a set of conceptual proxies that overlap significantly with the concept of robustness in the face of uncertainty [21,28,43,44]. We determine the strength of each proxy according to an assessed strength of substantial attributes that characterize it.

Table 3. The social-emotional preparedness program and its robustness to uncertainty based on the proxies-for-robustness.

Proxy	Definition	Social-Emotional Attribute	School-Based Application	Preparedness Plan Guidelines	Proxy Grade Compliance Estimation—Level 7	Proxy Grade Compliance Estimation—Level 9
Resilience	Rapid recovery of critical functions	Emotion regulation for proper functioning	- Educate for emotion regulation: • breathing techniques • a network of people to help with basic needs • prevent panic and hysteria • prevent burnout and long-term panic and hysteria • educate students and education staff for emotion regulation	- psychoeducation for emotion regulation and coping skills-dedicate physical education or life skills class lessons for physiological awareness and practice related to emotional responses - psychoeducation for emotion regulation and coping skills over a long time - include the importance of self-care through physiological well-being in physical education or life skills classes	3—high The major infrastructure will be down for no more than 48 h (electric and water), so proper emotional preparation should be adequate for coping with the event.	1—low The major infrastructure will be down for a week, as well as the food supply and personal communication. The emotional preparation is maybe good for the first days, but not for the whole period.
Redundancy	Multiple alternative solutions to be at hand	A network of peer support	- who do go to if the teacher is injured/unavailable - community network for immediate support—professional personnel or older neighborhood youth/ young adult - familiarization with local buildings - community network for long-term support - backup-plan B in case school facilities are damaged - use of community center if destruction of school building occurred	- assign more than one counselor per school - know your neighbor program - assign more than one counselor per school	3—high Due to the short period of downtime, the planned redundancy will be a good response to the earthquake damages.	2—medium The small community and school will help the population during the first week after the earthquake, including help with the immediate necessities (special food, taking care of younger, etc.)

Table 3. *Cont.*

Proxy	Definition	Social-Emotional Attribute	School-Based Application	Preparedness Plan Guidelines	Proxy Grade Compliance Estimation—Level 7	Proxy Grade Compliance Estimation—Level 9
Flexibility	Rapid modification of tools and methods in real-time for recovery from surprise	Exposure to a variety of personnel and learning platforms including distance-learning	- continued school-child connection - learning from different teachers and in different ways - short-term adaptiveness - familiarize students with staff that is not lead teachers - familiarize how to learn and access different platforms (e.g., face-to-face, online video chats, etc.) - Increasing familiar people in the community (adults, same age, teachers, neighbors)	- practice coping with unexpected changes - provide a range of survival skills to be used for coping with unexpected situations over a long time	3—high The usage of different types of tools and methods for learning and teaching allows high flexibility while adapting them to the situation (i.e., use of temporary buildings for classes, hybrid distance-offline learning)	2—medium The remote learning method may be affected by the shortage of electricity, but other platforms should be functional. In a level 9 earthquake the physical infrastructure of the school will be damaged, so need to be flexible with other solutions.
Adaptiveness	adjust goals and methods, and re-evaluate and revise assessment and decisions for the longer time range	Identify what needs are and are not met	- focus on specific topics for learning for long-term career building - provide mechanisms for solution consulting - food and shelter centers - decrease teaching and curriculum for non-core subjects - increase physical and mental health classes and supports - establish hotlines - food and shelter emergency centers - resiliency centers for social-emotional support	Increasing familiar resources (material and human resources)-good citizenship Good citizenship: providing help empathy Positive social relationship prosocial behavior	3—high Good citizenship will help the community to cope with an unexpected event. Decision-makers could get rational decisions because the community will be less panicked and stressed.	2—medium Good citizenship may overcome the obstacles caused by the shortage of critical infrastructure, but will not be an excellent solution.

Table 3. *Cont.*

Proxy	Definition	Social-Emotional Attribute	School-Based Application	Preparedness Plan Guidelines	Proxy Grade Compliance Estimation—Level 7	Proxy Grade Compliance Estimation—Level 9
Margins of Safety	Excess of the benefits beyond what's required—a buffer between adequacy and failure	Good citizenship and solidarity	- decrease at-school learning - increase social-emotional support personnel - Conform to governing guidelines - -solidarity - -rainy day security - shorter school days - distance learning - safety network - mentor programs including peer mentoring	- -sense of responsibility, good citizenship - -identify what is needed to maintain moral behavior and empathy - maintain moral behavior over time, even if resources are limited - -identify community mutual interests and create this overtime to support relationship building	3—high Extra resources will keep morale and solidarity high for the short term. The shock from the surprising event will be reduced, and the community functioning will be high. There will be a high level of social support.	2—medium Extra resources will not be enough to keep the high community functioning for the long term, but good citizenship will help to strengthen weaker people's physical and moral functioning.
Comprehensiveness	Addressing the multifaceted nature of the problem by taking an interdisciplinary system-wide coherence approach	Communication between various stakeholders	- dialogue with stakeholders - accessible child-friendly online information center - Increase trust with governing bodies - parent-teacher-child communication - create an online child-friendly online platform - local government and community - emergency and rescue services	Meet local governing units such as fire department, medical personnel, and others that are involved - identify stakeholders that can contribute to long-term coping	3—high The interdisciplinary operational response will be adequate for a level 7 earthquake.	2—medium Due to the lack of critical infrastructure, some features of the whole plan may be irrelevant

4.1.2. Qualitative Robustness Analysis Based on Proxies-for-Robustness

IGDT's qualitative analysis and assessment framework is supported by a set of conceptual proxies-for-robustness that reflect different aspects of robustness [21,45]. The proxies are useful in the qualitative assessment of immunity against failure under deep uncertainty. Ben-Haim [21] discusses six proxies-for-robustness: resilience, comprehensiveness, margins of safety, adaptiveness, flexibility, and redundancy. These are further described below and summarized in Table 3. Some activities or program components may address more than one proxy at the same time. For example, creating an interactive information website may address both comprehensiveness and adaptiveness proxies, as further elaborated on below.

Resilience: Resilience is the ability to maintain positive and effective coping strategies in the face of adversity [46]. Webster's dictionary [47] defines it as an ability to recover from or adjust easily to misfortune or change. Considerable research has been devoted to the study of resilience to better understand individuals and systems that display positive outcomes in the face of adversity. The concept of resilience is used in various economic, social, and environmental fields across various sectors including governance, commerce, industrial engineering, law, education, and psychology [31,48–54].

Redundancy: Redundancy is the availability of extra components (spares) that aim to improve the reliability of a system [55]. More abstractly, redundancy can also refer to the multiplicity of capabilities. Redundancy is extensively explored and applied in a variety of fields, particularly in critical and safety systems [56–60].

Flexibility: Flexibility is the ability to quickly adjust to change [61–63]. Flexibility is seen as a critical and strategic feature for adjusting to changes in different areas and situations, especially in cases of crises and emergencies [64–66].

Adaptiveness: Adaptiveness is the ability to make a long-term change to suit different conditions, circumstances, or a particular environment [21].

Margins of safety: Margins of safety are an excess of capability beyond the basic anticipated need. They allow room for imprecision, bad luck, or analytical error to avoid sizable losses over time. A margin of safety is necessary because in most cases valuation is imprecise, particularly in the face of an unpredictable future [67]. Examination and determination of margins of safety are applied in a wide range of fields, including environmental regulation [68,69].

Comprehensiveness: Comprehensiveness is defined as the extent to which organizations attempt to be exhaustive or inclusive in making integrated strategic decisions [70,71]. A comprehensive analysis examines multiple diverse aspects of the problem, from the perspectives of different disciplines.

Evaluating the proxies for robustness entails the identification of applicable substantive attributes of those proxies. For example, in banking systems, data is replicated using redundant backup systems. Such a measure raises the robustness in the face of uncertainty that stems from unexpected system failures. Different fields are characterized by different substantive attributes that are related to the above proxies for robustness. The IGDT framework is based on the analysis of decisions in the face of pre-defined proxies. A decision is then highly robust to uncertainty if it is strong in most or all of the proxies [21]. As can be seen, there is an overlap between the proxies for robustness and the goals of SEP. The novelty of the current work is in applying these definitions to consider social-emotional school programs for seismic level 7 and level 9 earthquakes.

4.2. Analysis Plan: Guidelines and an Application Example for Building a Robust Social-Emotional Preparedness Program

In the current research, we focus on building a SEPP by identifying social-emotional attributes and evaluating their robustness to uncertainty in terms of the strength of proxies for robustness. Social-emotional attributes that were identified and mapped in the research were aimed to increase the functionality of the population in the event of a destructive earthquake. We implemented the proxies through the lens of social-emotional processes within a school program framework. Children and teenagers are mandated to attend school

on an ongoing and daily basis. Within schools, they have access to many caring adults and professionals such as teachers, education staff, counselors, educational psychologists, and other relevant resources.

Another reason for focusing on school programs is that a SEPP can be implemented relatively easily, especially in comparison to addressing adults who do not regularly attend any governmental framework. As part of the program, it is possible to transfer and assimilate relevant content and develop social-emotional skills on an ongoing and daily basis. Furthermore, there is already great interest in enhancing efforts in developing curricula to improve students' emotional and social competences alongside their academic abilities [72], which has become even more relevant nowadays.

Such a program inherently produces a safety net for children and adolescents, who are highly vulnerable during a crisis. Harnessing this population as part of preparedness for earthquake emergencies achieves a dual purpose: first, disseminating information, knowledge, and developing social-emotional skills within the children or adolescents and their parents thereby increasing community resilience; and second, empowering children and adolescents, thereby increasing their motivation for cooperation, by actually becoming partners in implementing the plan. Importantly, the long-term implications of such a plan are far-reaching because as these children and adolescents grow to adulthood, they will continue to draw on these skills. In this sense, the short-term investment will have a lasting effect extending beyond proximal results and even transferable across generations.

To qualitatively assess social-emotional skills for robustness to uncertainty in earthquake events, we assess the strengths of the proxies for robustness: resilience, redundancy, flexibility, adaptiveness, margins of safety, and comprehensiveness. Each of the social-emotional skills can be implemented within the educational system to facilitate swift recovery and continued functioning in the case of a disastrous earthquake. These are considered no-regret because even if an earthquake does not occur, the population benefits from these actions. After all, a skill set is gained that can be transferred to other catastrophes, such as missile attacks, tornados, or pandemics, or during life transitions, such as from junior high to high school or from college to the workplace, thereby enhancing sustainable learning in education and beyond [73–75]. In what follows, the attributes of each proxy are defined and exemplified as contextualized in schools (see Table 3).

5. Defining and Evaluating the Social-Emotional Proxies for Robustness

5.1. Resilience

Community-based resilience is a combination of infrastructure as well as personal resources [76]. In terms of resilience in the face of an earthquake, it is the ability to recover from the catastrophe of a destructive earthquake. Clearly, the more a building aligns with guidelines for earthquake resilience, the less damage will be experienced. However, even in such a case, one's appraisal or interpretation of the earthquake will determine the emotional response and behaviors. The enhancement of resiliency that may be taught through SEPP may take the form of emotion regulation [24,77].

For example, seeing one's house in ruins will inevitably lead to an influx of negative emotions. This is considered normal coping and labeled acute reaction to stress when occurring during the first 48 h after the disaster [78]. However, if symptoms, such as re-experience, avoidance, or changes in reactions, cognition, and affect, continue and the person is unable to return to normalcy, then acute stress disorder (ASD), and later post-traumatic stress disorder (PTSD), is diagnosed. An event that is interpreted as traumatic, i.e., threatening one's physical or psychological well-being, to the extent that it leads to feelings of helplessness and insecurity, may have far-reaching detrimental consequences. However, if one is able to reappraise the situation and consider how to grow or adapt to it, then these negative ramifications may be assuaged. Thus, practicing reappraisal and knowing when to draw on suppression during day-to-day situations may provide benefits for daily functioning and bear through the rough times when a disaster occurs.

These forms of reinterpreting the situation (reappraisal) or withholding the expression of negative emotions (suppression) are types of emotion regulation that refers to one's adjusting of emotions to enable optimal functioning [79]. Teaching and refining emotion regulation strategies in schools enhance the resilience of teachers and personnel alongside the students. This, coupled with knowledge related to normative reactions to a disaster, strengthens the population with coping and healing from such situations. To strengthen resilience, emotion regulation may be taught as part of the school curriculum [35]. To this end, emotion regulation may be inculcated in children during learning as they develop subject knowledge. Furthermore, they may be taught emotion regulation as an important skill for both learning and life. For example, a child frustrated or angry with a grade may be provided strategies for reframing the situation (it is one grade to be averaged with work from the whole year) and suppress the expression of this emotion (not yell or crumple the exam) [80]. As part of the SEPP, these reactions may be considered as they would assist during a catastrophe. A good SEPP will increase resilience by teaching strategies and solutions that enable continued functioning in a way that decreases damage and vulnerability while increasing hardiness and social-emotional functioning.

For example, when faced with a destructive earthquake, it is natural to experience intense negative emotions such as anger, sadness, or fear. However, for different people, these emotions may lead to different responses. One may cry uncontrollably and fall into overthinking or ruminative emotion regulation thereby leading to an inability to act. Rumination refers to overthinking to the extent that one may not be able to function and it has been found to be related to depression [81]. As seen in Table 3, this form of resilience-building may be done by providing tools for how to cope with emotions through emotion regulation techniques, such as breathing or guided imagery [24,77]. In this same program, children and adolescents are taught how to identify maladaptive thoughts and how to reword them in a positive light that will lead to necessary actions. For example, homeroom teachers practice the skills that are taught by implementing them in coping with stressors in their students' daily lives and academic challenges, so that they can use these skills when a larger catastrophe occurs. To this end, teaching emotion regulation as part of the school curriculum is a no-regret measure as it enhances students' lives even if an earthquake does not occur.

5.2. Redundancy

Redundancy refers to having multiple social-emotional solutions for coping with a destructive earthquake. From a social-emotional perspective, this would mean having been familiarized with alternative infrastructure so that one feels the comfort of familiarity in the case that a backup plan is needed for school attendance. Using an infrastructure perspective, to understand the implementation of this to the social-emotional aspect, one may think about a situation in which the school facilities are damaged, and a local community center becomes the education facility to enable continued education. However, children and youth who do not know this and have never visited the community center, are likely to feel anxious, especially if they are already in a heightened state of arousal from coping with the earthquake. With this understanding, a program in Japan has scheduled meetings in community centers or other safe buildings within the community, for local municipality events that serve both to inform citizens about current events combined with a social gathering. This enables civilians to learn paths for getting to this location in addition to providing community cohesion [82].

From a social-emotional perspective, children should be familiar with the different facilities that will serve them when the school infrastructure is unsafe. Redundancy may also be considered in the form of interpersonal interactions. It is important that students meet with more than one representative from the supportive personnel at their school. To this end, more than one counselor should be on the educator staff. Children and adolescents prefer seeking support from people they know. This can be achieved by a more creative allocation of the current resources. For example, if there is a counselor assigned to each

grade, having a counselor from a different grade level join a few activities, even as an observer, would familiarize the whole student body with the personnel without requiring that counselor to do any extra work. If a destructive earthquake requires social-emotional support, then youth are already familiar with the second counselor and will be more open to sharing and learning from them as a source of support. During a level 7 seismic earthquake, a couple of counselors may suffice per grade level, whereas during a level 9 seismic earthquake the trauma may require more hours per child and over a longer period of time. It is therefore critical to think ahead and have a plan on how to adjust and be more efficient with the current resources when a disaster occurs, as well as consider how to expose children and adolescents to caring adults who may assist in the aftermath of an earthquake.

5.3. Flexibility

A preparedness program should also enhance flexibility to adjust the use of available materials to suffice for current needs. Flexibility enables real-time and short-term responses toward critical functioning in harsh circumstances and degraded conditions. Within schools, flexibility may be instilled by being able to learn in different ways and from several teachers or knowing how to learn from different platforms (e.g., online or face-to-face). To this end, exposure to a variety of personnel and learning platforms would enable flexibility to learn and maintain functioning even in the damage of a seismic-9 earthquake. Providing children with a safety net of caring adults [83], such as mentors who can assist when regular schooling is unavailable, or connecting students via peer mentoring also enable flexibility when the child/adolescent is required to engage in different learning spaces, including distance-learning if the school is damaged and unsafe. Flexibility has also been designated as an important 21st century skill that should be promoted in schools [84]. This refers to both inter-personal flexibility and flexibility in learning and strategy use. As such, promoting and educating for flexibility is a sure no-regret component as it contributes to both student competitiveness in the workforce and as a personal asset to prevail in the case of crisis. Such aspects can contribute to robustness in the case of an earthquake, as children and youth will be more equipped to receive instructions from several people in different ways.

5.4. Adaptiveness

Adapting to a situation is a long-term strategy related to adjusting goals and/or methods upon evaluation of the current situation. For example, moving food and shelter emergency centers that may have suffered from the earthquake to a different location. Support centers for social-emotional support or another sort of hotline may be established to aid young and old people to adjust and adapt to the new situation when regular resources do not work.

Because adaptiveness is a long-term strategy, the need for this would arise when circumstances have longevity. Clearly, survival skills would be necessary when the earthquake is highly destructive. However, beyond basic survival skills, good citizenship would be important in helping others to use survival skills that they may not have and adapt to the situation.

In terms of at-school learning, adjustments to the curriculum may be needed for providing more attention to mental and physical well-being, and more importantly, how to identify when one needs help to reach a place of mental and physical health. Interactive information centers where one can access information online serve as an additional source of support for post-event long-term adaptiveness. As part of educating for adaptiveness, students can be involved in creating such online resources, and they may also be taken to the support center to meet personnel as part of the process for creating imagery or content for use in the interactive information online center. By being part of a process that creates a platform for adaptive coping, students become more involved and can be educated to be creatively adaptive.

Recent work shows that creative adaptability, i.e., being able to adapt one's creativity, has benefits for coping with devastating situations [85,86]. By taking an active part in creating an information center for the community, students may apply their own creative adaptability. They may also be involved in spreading the word about the site to neighbors and others in their community [87]. The idea is to raise awareness of the possibility that such a catastrophe may occur and provide a point of ongoing interaction related to robustness.

5.5. Margins of Safety

SEPP will provide margins of safety that allow room for imprecision while at the same time avoiding sizable losses over time. To this end, investing in good citizenship and solidarity will have an added value in coping with damage from an earthquake. Good citizenship may arise when there is a feeling of solidarity within one's community. This can be instilled in children and adolescents by teaching empathy and moral reasoning. For example, in the school program [24,78], upper elementary school students (5th and 6th graders) are ambassadors for social-emotional support. They undergo age-appropriate training and learn about crisis preparedness. In this way, peers become a network of safety [88]. Similarly, providing children with a safety net of caring adults who can assist when regular schooling is unavailable, such as a mentor or peer mentoring, also encompasses margins of safety. The notion that one has the responsibility to contribute and care for the school and neighborhood instills good citizenship practices and empathy, which are of value even in regular times, and more so during a crisis when stress levels and uncertainty are high.

5.6. Comprehensiveness

While preparing for a significant catastrophic event such as an earthquake, there is a need for a collaborative and integrative approach from different stakeholders in the civilian arena, such as national government, local municipalities, emergency organizations, essential infrastructure units, private sector, or volunteer organizations. The civilian population is also considered a stakeholder but acts both as a service demander (from the mentioned organization) and as a service provider. At the same time, the population has active duties and roles during emergency events.

To build and maintain this complex and collaborative system, there is a need to have a routine of operations, which include doctrine development, integrative communication and command, control systems, joint exercises, and drills. To improve this joint operation, a periodic (e.g., annual) drill should be held with the main organizations within the civilian arena. One of the goals of the drill is to practice and refine collaborative skills among the different forces and organizations, including updating the field-data files and mutual communication channels.

A SEPP should take a collaborative and integrative approach to create a holistic framework that takes into account a variety of interfaces [24]. In this sense, providing several resources for social-emotional support is an example of how a preparedness program can increase comprehensiveness. Facilitating parent–teacher–child communication and providing child-friendly information also contribute to comprehensiveness. Familiarization with various stakeholders, such as emergency and rescue, ambulance medical staff, firefighters, and other entities, provides children and adolescents a broader picture with a multifaceted nature of coping with disasters. This may be applied based on the principles of the stakeholder theory [89] to create conversations among the most critical entities to establish collaboration in the case of a disaster. In particular, this can be implemented to establish comprehensive communication between all three levels of education (primary school, middle school, and high school) so that each one of them will have a specific role and contribute to the local preparedness program. Different aspects may be accentuated at different age groups. In this way, social-emotional involvement or community outreach programs in high schools will receive assignments that draw on their strengths. For example, adolescents involved in drama or cinema classes will be able to create relevant and user-friendly media that could be disseminated independently or through an interactive site to

help in the preparation, information related to coping during the catastrophe, and in coping with the aftermath. STEM focused students may create solutions for problems or estimate earthquake parameters based on data. This could be geared towards the establishment of a central knowledge website for the school that is adapted to each age group.

5.7. The Social-Emotional School Program

Looking at several intervention programs aimed at building robustness to withstand earthquakes, SEPPs may be implemented both within schools and on a national or local government level [90]. From our review of the literature and crisis-related interventions, we have not seen differential preparedness for short-term or long-term crisis coping. The research and programs we have found are related to preparedness in general, without considering differences in whether the crisis coping will be for 48 h as with a level 7 earthquake versus a prolonged coping period as with a level 9 earthquake. However, in prolonged crisis coping, there may be more burnout in coping, as well as feelings of lack of control and learned helplessness.

Preparedness for a seismic level 7 earthquake requires preparing for 48 h of vital infrastructure disconnection, injury, damage, or death. As described in Table 2, electricity and petrol may not be available, people will likely experience panic and anxiety. In this case, some buildings or parts of buildings may still be standing and in working order, and the collective suffering due to the crisis will be partial. People will be able to help each other and even provide shelter to those whose homes have been ruined. It is likely that schools built with proper earthquake codes will be standing and could function, providing a safe space where children and adolescents can come to share their feelings and difficulties coping, perhaps returning to normal learning fairly quickly thereby maintaining normalcy even if certain buildings in the community are still damaged. The short-term recuperation period should not result in long-term trauma responses for those who were not directly hit by the earthquake. At the same time, without proper preparedness, people will not know what to do, be surprised, and feel out of control. Only when vital infrastructure will be reconnected, will they feel better as they begin to resume essential functioning. Social-emotional preparation will enable to reduce vulnerability and increase the resilience of the population. Because of the relatively short amount of time, post-event recovery efforts will take place fairly quickly.

Unlike a seismic level 7 earthquake, during a seismic level 9 earthquake, the long-term damage to infrastructure and buildings will lead to highly restricted accessibility due to damage to road infrastructure and buildings. Thus, we expect that after the first few days, the longevity of the situation will have further implications for children and adolescents as the adults in their environment become worn out due to the ongoing and unpredictable situation, lack of shelter, and uncertainty concerning basic food and medical supplies. Children and adolescents may have to take a more active role to not only provide for themselves but also for people in their proximity. In such situations, when there is long-term coping with a situation that is out of one's control, that lack of control for a prolonged time may lead to depression symptoms. Therefore, it is important to educate children on strategies to maintain positive emotion and decrease anxiety, stress, or depression for the long haul of stabilizing after a disastrous earthquake. This form of emotional management is at the core of social-emotional learning [91].

Another important factor for long-term recuperation is the inter-personal connections with people in close proximity. Limitations of basic supplies such as electricity, water, and food would require people to congregate and help each other. It may be in the form of survival skills, such as igniting a fire for keeping warm or sifting through ruins to locate supplies or even people who are trapped and are waiting for rescue teams. Thus, there is more value in comprehensiveness and stakeholder proxies for long-term coping with a larger seismic magnitude earthquake. Having knowledge of this beforehand may provide a source of calm when coping with the actual devastation. The burnout and sense of lack

of control may be diminished if people are provided information beforehand creating a sense of certainty thereby increasing feelings of safety.

6. Findings and Discussion

In the current study, we defined guidelines for building a SEPP based on social-emotional competences [91] and proxies-for-robustness from IGDT [28] and built a SEPP for a seismic level 9 earthquake. This multi-disciplinary approach enabled the construction of a program that consists of school-based applications that were associated with social-emotional proxies for robustness. The strength of the social-emotional proxies for robustness was evaluated for both seismic level 9 and seismic level 7.

The evaluation procedure for both seismic level 9 and seismic level 7 employs operational plans for natural disasters, including earthquakes, lessons learned from the last 15 years, large-scale earthquakes, and similar scale events, such as floods and hurricanes, which caused similar effects. An important contribution of the current work is that it extends prior work on social-emotional preparedness by providing guidelines based on IGDT. The suggested framework for SEPP contains substantial attributes of robustness, which provide useful guidelines for practitioners as they sort through possible implementations of programs. The outcomes reflect comparative values, i.e., seismic level 7 vs. seismic level 9, rather than absolute values. A concise explanation is presented in Table 3.

The results, as presented in Table 3, indicate that the robustness of the SEPP is greater for seismic level 7, as the strength of the social-emotional proxies for robustness for seismic level 7 are higher than the strength of the social-emotional proxies for robustness for seismic level 9. The level of robustness is visualized in the Radar chart in Figure 2. The greater the polygon area is, the higher the level of robustness. As presented, planning for a more extreme situation of seismic level 9 resulted in a larger level of robustness for the lesser situation of seismic level 7. Examination of Figure 2 shows that the robustness to uncertainty of the SEPP is consistently high for level 7 earthquakes, but only moderate for seismic level 9.

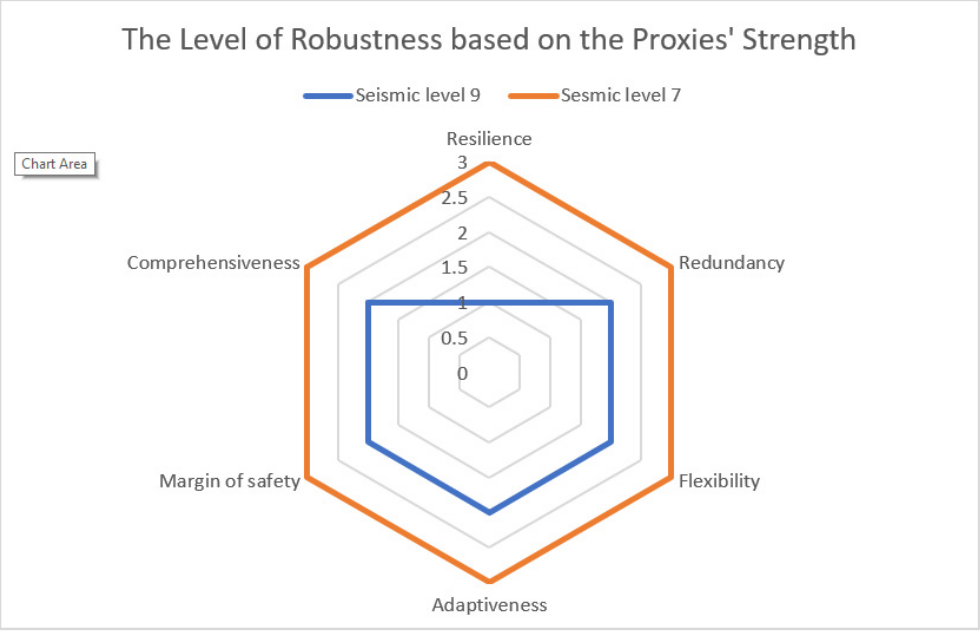

Figure 2. The Level of Robustness based on the Proxies' Strength.

The results indicate that it is necessary to enhance the SEPP for seismic intensity 9 if we want to achieve the level of robustness against uncertainty of the SEPP for seismic intensity 7. Figure 3 shows a schematic illustration of the application of the research methodology and findings.

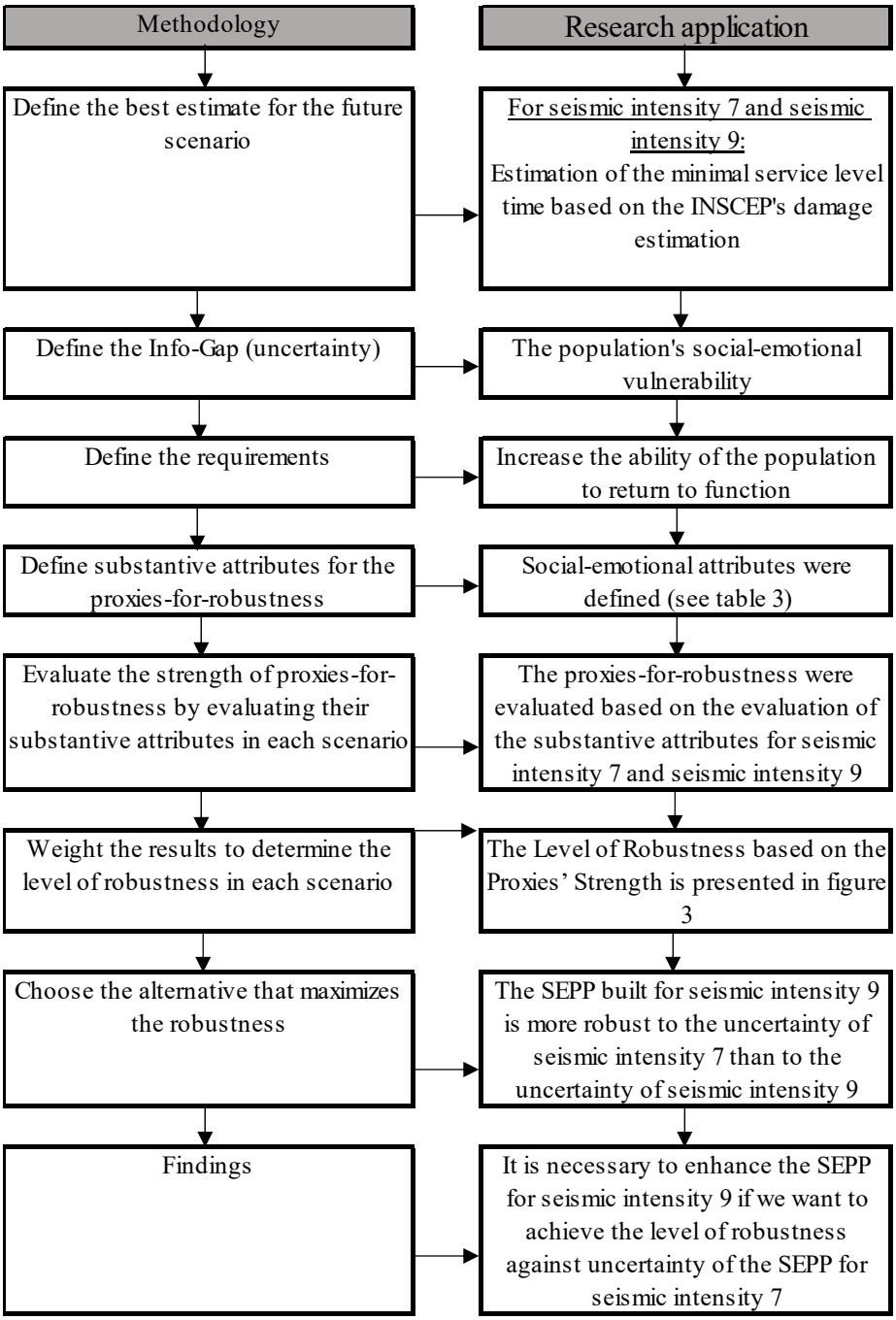

Figure 3. Schematic illustration of the application of the research methodology and findings.

7. Conclusions

Social-emotional preparedness is a critical factor in the ability of the population to recover and return to functioning from an extreme adverse event such as an earthquake. In this way, it contributes to social sustainability [15,92] beyond infrastructure. Social-emotional preparedness programs are usually evidence-based programs, based on past occurrences that are inevitably different from future occurrences (which have not yet happened in reality). Such planning is not reliable in the face of the deep uncertainty that characterizes an extreme earthquake event. In the present study, an innovative and unique multidisciplinary methodology was developed, which includes theoretical and practical aspects for constructing a SEPP that is robust in the face of uncertainty in the event of an extreme earthquake. An important contribution of the current work is in extending

prior work on social-emotional preparedness by providing guidelines based on IGDT for evaluating the robustness to uncertainty of a SEPP.

The current work implemented the IGDT proxies-for-robustness to school programs for coping with earthquakes, as schools have a statutory responsibility to promote the well-being of their students. When applying a program to increase robustness against uncertainty in schools, both children/adolescents and their networks are influenced. We considered school programs and found that when applying principles based on the proxies, programs may be evaluated and improved with respect to their robustness to uncertainty. This type of preparedness will have benefits for other crises as well.

Further research can elaborate on no-regret preparedness programs for other natural disasters, such as wildfires, hurricanes, pandemics, cold waves, etc. Additionally, a comparison can be made between different disasters and their preparedness proxies using the proposed methodology. Finally, there is a need to look into additional platforms for the implementation of preparedness programs in the civilian arena (apart from schools).

Author Contributions: The first and second authors made an equal contribution. Conceptualization, S.D.; data curation, G.L. and R.A.; formal analysis, G.L. and R.A.; funding acquisition, A.B.-E.; investigation, S.D., A.B.-E. and R.A.; methodology, S.D., A.B.-E. and Y.B.-H.; project administration, S.D., A.B.-E., Y.B.-H. and R.A.; supervision, S.D., A.B.-E. and Y.B.-H.; validation, S.D. and A.B.-E.; visualization, S.D.; writing—original draft, S.D., A.B.-E. and R.A.; writing—review & editing, S.D., A.B.-E., Y.B.-H. and R.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Israel Ministry of Science and Technology, and the National Emergency Management Authority of the Israel Ministry of Defense, grant number 2027131.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Doocy, S.; Daniels, A.; Packer, C.; Dick, A.; Kirsch, T.D. The Human Impact of Earthquakes: A Historical Review of Events 1980–2009 and Systematic Literature Review. *PLoS Curr.* **2013**, *5*. [CrossRef] [PubMed]
2. Federal Emergency Management Agency (FEMA). *Hazus® Estimated Annualized Losses for the United States*; FEMA: Washington, DC, USA, 2017.
3. Lei, J.; Xie, F.; Mishra, O.P.; Lu, Y.; Zhang, G.; Li, Y. The 2011 Yingjiang, China, earthquake: A volcano-related fluid-driven earthquake? *Bull. Seismol. Soc. Am.* **2012**, *102*, 417–425. [CrossRef]
4. Wilkinson, S.; Grant, D.; Williams, E.; Paganoni, S.; Fraser, S.; Boon, D.; Mason, A.; Free, M. Observations and implications of damage from the magnitude Mw 6.3 Christchurch, New Zealand earthquake of 22 February 2011. *Bull. Earthq. Eng.* **2012**, *11*, 107–140. [CrossRef]
5. Arriagada, C.; Arancibia, G.; Cembrano, J.; Martínez, F.; Carrizo, D.; Jan, M.V.S.; Sáez, E.; González, G.; Rebolledo, S.; Sepúlveda, S.; et al. Nature and tectonic significance of co-seismic structures associated with the Mw 8.8 Maule earthquake, central-southern Chile forearc. *J. Struct. Geol.* **2011**, *33*, 891–897. [CrossRef]
6. Araneda, J.; Rudnick, H.; Mocarquer, S.; Miquel, P. Lessons from the 2010 Chilean earthquake and its impact on electricity supply. In Proceedings of the 2010 International Conference on Power System Technology, Zhejiang, China, 24–28 October 2010; IEEE: New York, NY, USA, 2010; pp. 1–7.
7. OECD. Financial Management of Earthquake Risk. 2018. Available online: www.oecd.org/finance/Financial-Management-of-Earthquake-Risk.htm (accessed on 5 May 2022).
8. Özdamar, L.; Ekinci, E.; Küçükyazici, B. Emergency logistics planning in natural disasters. *Ann. Oper. Res.* **2004**, *129*, 217–245. [CrossRef]
9. Sheu, J.-B. An emergency logistics distribution approach for quick response to urgent relief demand in disasters. *Transp. Res. Part E Logist. Transp. Rev.* **2007**, *43*, 687–709. [CrossRef]
10. Lin, Y.-H.; Batta, R.; Rogerson, P.A.; Blatt, A.; Flanigan, M. Location of temporary depots to facilitate relief operations after an earthquake. *Socio-Econ. Plan. Sci.* **2012**, *46*, 112–123. [CrossRef]
11. Lindell, M.K.; Perry, R.W. The Protective Action Decision Model: Theoretical Modifications and Additional Evidence. *Risk Anal.* **2011**, *32*, 616–632. [CrossRef]
12. Lu, X.; Han, Z. Emergency management in China: Towards a comprehensive model? *J. Risk Res.* **2018**, *22*, 1425–1442. [CrossRef]

13. Wu, G.; Han, Z.; Xu, W.; Gong, Y. Mapping individuals' earthquake preparedness in China. *Nat. Hazards Earth Syst. Sci.* **2018**, *18*, 1315–1325. [CrossRef]
14. Görmez, N.; Köksalan, M.; Salman, F.S. Locating disaster response facilities in Istanbul. *J. Oper. Res. Soc.* **2011**, *62*, 1239–1252. [CrossRef]
15. UN General Assembly. UN General Assembly, Transforming Our World: The 2030. Agenda for Sustainable Development, 21 October 2015, A/RES/70/1. 2015. Available online: https://www.refworld.org/docid/57b6e3e44.html (accessed on 5 May 2022).
16. Tafuro, A.; De Matteis, F.; Preite, D.; Costa, A.; Mariella, L.; Treviso, G. Social sustainability and local authroieis: What is the relationship between spending commitments and social issues? *Socio-Econ. Plan. Sci.* **2019**, *67*, 120–132. [CrossRef]
17. World Bank. *Development and Climate Change: The World Bank Group at Work*; World Bank: Washington, DC, USA, 2009.
18. Heltberg, R.; Siegel, P.B.; Jorgensen, S.L. Addressing Human Vulnerability to Climate Change: Toward a 'No Regrets' Approach. *Glob. Environ. Chang.* **2009**, *19*, 89–99. [CrossRef]
19. Lehrer, E. A wide range no-regret theorem. *Games Econ. Behav.* **2003**, *42*, 101–115. [CrossRef]
20. Hart, S.; Mas-Colell, A. A Simple Adaptive Procedure Leading to Correlated Equilibrium. *Econometrica* **2000**, *68*, 1127–11500. [CrossRef]
21. Ben-Haim, Y. *The Dilemmas of Wonderland: Decisions in the Age of Innovation*; Oxford University Press: Oxford, UK, 2018.
22. Hasani, A.; Mokhtari, H. Redesign strategies of a comprehensive robust relief network for disaster management. *Socio-Econ. Plan. Sci.* **2018**, *64*, 92–102. [CrossRef]
23. Bolia, N.B. Robust scheduling for large scale evacuation planning. *Socio-Econ. Plan. Sci.* **2019**, *71*, 100756.
24. Hamiel, D.; Wolmer, L.; Spirman, S.; Laor, N. Comprehensive Child-Oriented Preventive Resilience Program in Israel Based on Lessons Learned from Communities Exposed to War, Terrorism and Disaster. *Child Care Q.* **2013**, *42*, 261–274. [CrossRef]
25. Sánchez-Pujalte, L.; Mateu, D.N.; Etchezahar, E.; Yepes, T.G. Teachers' Burnout during COVID-19 Pandemic in Spain: Trait Emotional Intelligence and Socioemotional Competencies. *Sustainability* **2021**, *13*, 7259. [CrossRef]
26. Shapira, A. *Preparation Framework for Devastating Earthquake Events in Israel*; INSCEP, Prime Minister's Office: Jerusalem, Israel, 2011. (In Hebrew)
27. Applied Technology Council (ATC). *Earthquake Damage Evaluation Data for California (ATC-13)*; ATC: Redwood City, CA, USA, 1985.
28. Ben-Haim, Y. *Info-Gap Decision Theory: Decisions under Severe Uncertainty*, 2nd ed.; Elsevier: Amsterdam, The Netherlands, 2006.
29. Ben-Haim, Y.; Osteen, C.D.; Moffitt, L.J. Policy dilemma of innovation: An info-gap approach. *Ecol. Econ.* **2013**, *85*, 130–138. [CrossRef]
30. Ben-Haim, Y. Does a better model yield a better argument? An info-gap analysis. *Proc. R. Soc. A Math. Phys. Eng. Sci.* **2017**, *473*, 20160890. [CrossRef]
31. Ben-Haim, Y. Assessing 'beyond a reasonable doubt' without probability: An info-gap perspective. *Law Probab. Risk* **2019**, *18*, 77–95. [CrossRef]
32. Halpern, B.S.; Regan, H.M.; Possingham, H.; McCarthy, M.A. Accounting for uncertainty in marine reserve design. *Ecol. Lett.* **2006**, *9*, 2–11. [CrossRef] [PubMed]
33. Coles, J.B.; Zhuang, J.; Yates, J. Case study in disaster relief: A descriptive analysis of agency partnerships in the aftermath of the January 12th, 2010 Haitian earthquake. *Socio-Econ. Plan. Sci.* **2012**, *46*, 67–77. [CrossRef]
34. Geological Survey of Israel. 2022. Earthquake Search Results. Available online: https://earthquake.co.il/heb/earthquake/searchEQS.php (accessed on 5 May 2022).
35. Ben-Eliyahu, A. Academic Emotional Learning: A Critical Component of Self-Regulated Learning in the Emotional Learning Cycle. *Educ. Psychol.* **2019**, *54*, 84–105. [CrossRef]
36. Jennings, P.A.; Greenberg, M.T. The Prosocial Classroom: Teacher Social and Emotional Competence in Relation to Student and Classroom Outcomes. *Rev. Educ. Res.* **2009**, *79*, 491–525. [CrossRef]
37. Weissberg, R.P.; Durlak, J.A.; Domitrovich, C.E.; Gullotta, T.P. Social and emotional learning: Past, present, and future. In *Handbook for Social and Emotional Learning: Research and Practice*; Durlak, J.A., Domitrovich, C.E., Weissberg, R.P., Gullotta, T.P., Eds.; Guilford: New York, NY, USA, 2015; pp. 3–19.
38. Greenberg, M.T.; Weissberg, R.P.; O'Brien, M.U.; Zins, J.E.; Fredericks, L.; Resnik, H.; Elias, M.J. Enhancing school-based prevention and youth development through coordinated social, emotional, and academic learning. *Am. Psychol.* **2003**, *58*, 466–474. [CrossRef]
39. National Institute for Health and Clinical Excellence. Social-Emotional Wellbeing in Secondary Education. NICE Public Health Guidance. 2009. Available online: https://www.nice.org.uk/guidance/ph20 (accessed on 5 May 2022).
40. Mosley, H.; Mayer, A. *Benchmarking National Labour Market Performance: A Radar Chart Approach*; (No. FS I 99-202); WZB Discussion Paper; WZB: Berlin, Germany, 1999.
41. Di Maria, F.; Daskal, S.; Ayalon, O. A methodological approach for comparing waste water effluent's regulatory and management frameworks based on sustainability assessment. *Ecol. Indic.* **2020**, *118*, 106805. [CrossRef]
42. Adams, V.M.; Pressey, R.L. An info-gap model to examine the robustness of cost-efficient budget allocations. *Vulnerability Uncertain. Risk Anal. Modeling Manag.* **2011**, 971–979. [CrossRef]
43. Hayes, K.R.; Barry, S.C.; Hosack, G.R.; Peters, G.W. Severe uncertainty and info-gap decision theory. *Methods Ecol. Evol.* **2013**, *4*, 601–611. [CrossRef]

44. Ben-Haim, Y. Uncertainty, probability and information-gaps. *Reliab. Eng. Syst. Saf.* **2004**, *85*, 249–266. [CrossRef]
45. Ben-Haim, Y.; Demertzis, M. Decision Making in Times of Knightian Uncertainty: An Info-Gap Perspective. *Economics* **2016**, *10*, 1–30. [CrossRef]
46. Luthar, S.S.; Cicchetti, D.; Becker, B. The Construct of Resilience: A Critical Evaluation and Guidelines for Future Work. *Child Dev.* **2000**, *71*, 543–562. [CrossRef] [PubMed]
47. Merriam-Webster Dictionary. Available online: https://www.merriam-webster.com/dictionary/resilience (accessed on 5 May 2022).
48. Allen, C.R.; Cumming, G.S.; Garmestani, A.S.; Taylor, P.D.; Walker, B.H. Managing for resilience. *Wildl. Biol.* **2011**, *17*, 337–349. [CrossRef]
49. Djalante, R.; Thomalla, F. Community resilience to natural hazards and climate change impacts: A review of definitions and operational frameworks. *Asian J. Environ. Disaster Manag.* **2010**, *3*, 3.
50. Hooper, L.M. Individual and Family Resilience: Definitions, Research, and Frameworks Relevant for All Counselors. *Ala. Couns. Assoc. J.* **2009**, *35*, 19–26.
51. Hosseini, S.; Barker, K.; Ramirez-Marquez, J.E. A review of definitions and measures of system resilience. *Reliab. Eng. Syst. Saf.* **2016**, *145*, 47–61. [CrossRef]
52. Leitner, H.; Sheppard, E.; Webber, S.; Colven, E. Globalizing urban resilience. *Urban Geogr.* **2018**, *39*, 1276–1284. [CrossRef]
53. Ribeiro, J.P.; Barbosa-Povoa, A. Supply Chain Resilience: Definitions and quantitative modelling approaches–A literature review. *Comput. Ind. Eng.* **2018**, *115*, 109–122. [CrossRef]
54. Southwick, S.M.; Bonanno, G.A.; Masten, A.S.; Panter-Brick, C.; Yehuda, R. Resilience definitions, theory, and challenges: Interdisciplinary perspectives. *Eur. J. Psychotraumatol.* **2014**, *5*, 25338. [CrossRef]
55. Boland, P.J.; El-Neweihi, E.; Proschan, F. Redundancy importance and allocation of spares in coherent systems. *J. Stat. Plan. Inference* **1991**, *29*, 55–65. [CrossRef]
56. Brock, T.; Bigler, F.; Frampton, G.; Hogstrand, C.; Luttik, R.; Martin-Laurent, F.; Topping, C.J.; van der Werf, W.; Rortais, A. Ecological recovery and resilience in environmental risk assessments at the European Food Safety Authority. *Integr. Environ. Assess. Manag.* **2018**, *14*, 586–591. [CrossRef] [PubMed]
57. Li, G.; Zhou, Z.; Hu, C.; Chang, L.; Zhang, H.; Yu, C. An optimal safety assessment model for complex systems considering correlation and redundancy. *Int. J. Approx. Reason.* **2018**, *104*, 38–56. [CrossRef]
58. Nowell, B.; Bodkin, C.P.; Bayoumi, D. Redundancy as a strategy in disaster response systems: A pathway to resilience or a recipe for disaster? *J. Contingencies Crisis Manag.* **2017**, *25*, 123–135. [CrossRef]
59. Ong, M.-S.; Coiera, E. Safety through redundancy: A case study of in-hospital patient transfers. *BMJ Qual. Saf.* **2010**, *19*, e32. [CrossRef]
60. Zolghadri, A. A redundancy-based strategy for safety management in a modern civil aircraft. *Control Eng. Pract.* **2000**, *8*, 545–554. [CrossRef]
61. Kulatilaka, N.; Marks, S.G. The strategic value of flexibility: Reducing the ability to compromise. *Am. Econ. Rev.* **1988**, *78*, 574–580.
62. Volberda, H.W. Strategic flexibility creating dynamic competitive advantages. In *The Oxford Handbook of Strategy*; Oxford University Press: Oxford, UK, 2003.
63. Webb, G.R.; Chevreau, F.R. Planning to improvise: The importance of creativity and flexibility in crisis response. *Int. J. Emerg. Manag.* **2006**, *3*, 66–72. [CrossRef]
64. Brozovic, D. Strategic Flexibility: A Review of the Literature. *Int. J. Manag. Rev.* **2016**, *20*, 3–31. [CrossRef]
65. Kickert, W.J. The magic word flexibility. *Int. Stud. Manag. Organ.* **1984**, *14*, 6–31.
66. Zagelmeyer, S.; Heckmann, M. Flexibility and crisis resistance: Quantitative evidence for German establishments. *Int. J. Manpow. Civ. Aircr. Control Eng. Pract.* **2013**, *8*, 545–554. [CrossRef]
67. Klarman, S.A. *Margin of Safety*; Harper Business: New York, NY, USA, 1991.
68. Ames, D.P.; Lall, U. Developing Total Maximum Daily Loads Under Uncertainty: Decision Analysis and the Margin of Safety. *J. Contemp. Water Res. Educ.* **2008**, *140*, 37–52. [CrossRef]
69. Thompson, K.H. Margin of safety as a risk-management concept in environmental legislation. *Colum. J. Envtl. L.* **1979**, *6*, 1.
70. Fredrickson, J.W.; Mitchell, T.R. Strategic decision processes: Comprehensiveness and performance in an industry with an unstable environment. *Acad. Manag. J.* **1984**, *27*, 399–423.
71. Fredrickson, J.W. The comprehensiveness of strategic decision processes: Extension, observations, future directions. *Acad. Manag. J.* **1984**, *27*, 445–466.
72. Osher, D.; Kidron, Y.; Brackett, M.; Dymnicki, A.; Jones, S.; Weissberg, R.P. Advancing the science and practice of social and emotional learning: Looking back and moving forward. *Rev. Res. Educ.* **2016**, *40*, 644–681. [CrossRef]
73. Ben-Eliyahu, A. Sustainable Learning in Education. *Sustainability* **2021**, *13*, 4250. [CrossRef]
74. Hays, J.; Reinders, H. Sustainable learning and education: A curriculum for the future. *Int. Rev. Educ.* **2020**, *66*, 29–52. [CrossRef]
75. Peris-Ortiz, M.; Lindahl, J.M. (Eds.) *Sustainable Learning in Higher Education: Developing Competence for the Global Marketplace*; Springer International Publishing: Berlin/Heidelberg, Germany, 2015.
76. Norris, F.H.; Stevens, S.P.; Pfefferbaum, B.; Wyche, K.F.; Pfefferbaum, R.L. Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness. *Am. J. Community Psychol.* **2008**, *41*, 127–150. [CrossRef]
77. The Cohen-Harris Resilience Center. Education Resilience Program (In Hebrew). Available online: https://ch-resilience.org.il/education/ (accessed on 5 May 2022).

78. American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders (DSM-5®)*; American Psychiatric Publishing: Washington, DC, USA, 2013.
79. Gross, J.J.; John, O.P. Individual differences in two emotion regulation processes: Implications for affect, relationships, and well-being. *J. Pers. Soc. Psychol.* **2003**, *85*, 348–362. [CrossRef]
80. Ben-Eliyahu, A.; Linnenbrink-Garcia, L. Extending self-regulated learning to include self-regulated emotion strategies. *Motiv. Emot.* **2012**, *37*, 558–573. [CrossRef]
81. Nolen-Hoeksema, S.; Morrow, J.; Fredrickson, B.L. Response styles and the duration of episodes of depressed mood. *J. Abnorm. Psychol.* **1993**, *102*, 20–28. [CrossRef] [PubMed]
82. Kitagawa, K. Exploring 'everyday-life preparedness': Three case studies from Japan. *Int. J. Disaster Risk Reduct.* **2019**, *34*, 265–274. [CrossRef]
83. Ben-Eliyahu, A.; Rhodes, J.E.; Scales, P. The Interest-Driven Pursuits of 15 Year Olds: "Sparks" and Their Association with Caring Relationships and Developmental Outcomes. *Appl. Dev. Sci.* **2014**, *18*, 76–89. [CrossRef]
84. Geisinger, K.F. 21st Century Skills: What Are They and How Do We Assess Them? *Appl. Meas. Educ.* **2016**, *29*, 245–249. [CrossRef]
85. Orkibi, H. Creative Adaptability: Conceptual Framework, Measurement, and Outcomes in Times of Crisis. *Front. Psychol.* **2021**, *11*, 588172. [CrossRef]
86. Orkibi, H.; Ben-Eliyahu, A.; Reiter-Palmon, R.; Testoni, I.; Biancalani, G.; Murugavel, V.; Gu, F. Creative adaptability and emotional well-being during the COVID-19 pandemic: An international study. *Psychol. Aesthet. Creat. Arts* **2021**. [CrossRef]
87. United States Department of Homeland Security, Federal Emergency Management Agency (FEMA). *Student Tools for Emergency Planning (STEP) Program: A Curriculum for 4th and 5th Grade St.*; FEMA: Washington, DC, USA, 2015. Available online: https://www.ready.gov/student-tools-emergency-planning-step (accessed on 5 May 2022).
88. Rhodes, J.E. A theoretical model of youth mentoring. In *Handbook of Youth Mentoring*; DuBois, D.L., Karcher, M.A., Eds.; Sage: Thousand Oakes, CA, USA, 2005; pp. 30–43.
89. Laplume, A.O.; Sonpar, K.; Litz, R.A. Stakeholder Theory: Reviewing a Theory That Moves Us. *J. Manag.* **2008**, *34*, 1152–1189. [CrossRef]
90. Public Health England, UCL Institutes of Health Equity, Local Action on Health Inequalities: Building Children and Young People's Resilience in Schools. 2014. Available online: https://www.gov.uk/government/publications/local-action-on-health-inequalities-evidence-papers (accessed on 5 May 2022).
91. Elias, M.J. Social-Emotional and Character Development and Academics as a Dual Focus of Educational Policy. *Educ. Policy* **2009**, *23*, 831–846. [CrossRef]
92. US Official Website of the Department of Homeland Security "Ready". Available online: https://www.ready.gov (accessed on 5 May 2022).