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Coupling School Risk Reduction Strategies with LAMESA (Life-Saving Automated "Mesa" to Endure Seismic Activity) for Kindergarten

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The study linked school risk reduction and disaster preparedness strategy using a designed automated study desk for kindergarten. This desk, LAMESA (Life-saving Automated "Mesa" to Endure Seismic Activity), aimed to provide the education system with a resilient study desk for kindergarten. Design and development research used lightweight but highly strong and elastic materials to build the automated desk conforming to the kindergarten standards. The system and program designs ensured good peak ground acceleration (PGA) and a fix response time (4 sec.) to effectively and efficiently facilitate "duck (drop), cover, hold" actions of kindergartens to shield them from debris in the eventuality of a strong seismic activity. Purposively chosen experts (engineers, scientists, and programmers) and stakeholders (kindergarten teachers, the laboratory school principal, parents, and district supervisor) evaluated the automated desk as excellent in features, design, and visual; as a warning system when earthquakes occur; as safety infrastructure for students; and as a learning tool. For holistic packaging, the desk may undergo strength test and is also recommended to include ad materials and training kits.

Key words: automated earthquake desk, disaster preparedness, disaster risk reduction, kindergarten, response time

INTRODUCTION

Most countries seek for the most competitive and dynamic knowledge-based economy capable of sustainable economic growth and improved global stance (Lane 2014, OECD) that translates to low risk, better, and comfortable lives of its citizens. However, sustaining a low-risk environment is a real challenge to most countries when people encounter extreme conditions of disasters. The dominance of public apathy over the causes (climate change, earth processes, and natural disaster) contributory to greater risk and casualty draws from a public deficit of information and comprehension (Kahan *et al.* 2012). This misinformation, non-information, and non-comprehension of related concepts that negates achieving knowledge-based society may be averted by educating the citizens. This education inclines to depend on scientific literacy, numeracy, information, and learning of essential life skills (UNESCO 2013) of the locals to train citizens to be informed and decisive in all life aspect. This literacy

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subsumes deep understanding of the concepts and processes of science, and how this knowledge may help reduce risk and mitigate a disaster in a conspicuously altered world by climatological changes.

Scientific Literacy and Natural Disaster Preparedness

The development of scientific literacy may be observed in two basic stages – type 1 relates to cognitive achievement in science; and type II relates to competence about science and its interrelation with everyday contexts even in the fields of climatic change and natural disasters, in terms of problem solving, decision making, attitude, and values (Roberts 2007). Thus, scientific literacy completely prepares (passively and actively) the youth and the citizens to face risk and disaster with informed decisions. Passive preparation (type 1 preparation to scientific literacy) includes providing a holistic nature of the science concepts related to natural disasters and how to reduce risks and mitigate disaster. Additionally, this preparation may include teaching the concepts of science related to natural disaster and preparing disaster manuals, stockpiling of relief goods, and developing computer listing of resources and personnel (Gregario 2010). Active disaster preparedness includes developing comprehensive response plans to ensure timely and effective delivery of relief. It may conform to developing type II and completing acquisition of scientific literacy necessary for risk and disaster preparedness.

Researchers believe that while the public should know about science in order to live more effectively and safely with respect to the natural world (DeBoer 2000, Okada 2013), men and women of science should be more passionate in providing public scientific and technological knowledge to highlight "sharing of knowledge for action; use of multidisciplinary approach to research; and building systems resilience through local, national, regional, and international partnerships" (Aitsi-Selmi *et al.* 2015). The first prioritizes sharing and disseminating scientific information and technological advances and translating them into practical methods for disaster risk reduction (DRR). This schema accentuates the intentions of the study to couple passive preparedness (capacity building at all levels) with developing tools (automated desk) for active preparedness and targeting the youngsters (kindergartens) who seem to be at high risk. This study goal may promote high rates of survival in the eventuality of disaster and risk.

The Philippine Scenario

Among the different natural calamities and human-induced hazards, the Philippines is critically preparing for geologic hazards, – particularly earthquake. News on "The Big One" (Sabillo 2015) stimulated serious attempts to earthquake preparedness. Notably, Sabillo reported that the Philippine Institute of Volcanology and Seismology (PHIVOLCS) predicts the possibility of another offshore 8.5-magnitude earthquake, a major West Valley fault movement that could result in a tremendous disaster. High feasibility of the "The Big One" to happen is induced by the fact that the Philippines lies along the Ring of Fire, which makes the country vulnerable to many geologic movements and possible hazards.

Part of the critical preparation for "The Big One" includes a structure alarm system in municipalities; collaboration with the United Nations Champion for Disaster Risk Reduction and Climate Change Adaptation for Asia-Pacific for more information on the major faults; ensuring structural integrity of buildings and other preparedness measures as based on Sendai framework (UNISDR 2015); and the common "duck (drop), cover, hold" protocol (drop to the floor, cover your head, and hold on to a solid object) (DepEd-UNICEF 2008).

While resilient infrastructure dominates the earthquake preparedness scheme in many countries (Cole 2015) including the Philippines, Cole reported that a middle-eastern scientist – Arthur Brutter in 2010 – argued that this system is a long-term solution to earthquake preparedness. In fact, many scientists and engineers explored the possibilities of simulating seismic activities to check the strength, stability, and resilience of an infrastructure by constructing "shake tables" (Nakashima *et al.* 2008, Barnes 2012, Stehman 2014). This model provides engineers with the seismic response of the building or infrastructure and a way to create the worst case scenario and the stability limit of the building (Brown 2007). Earthquake-resistant buildings may be a long-term solution adhering to modern building codes; however, this may not be the immediate need for "The Big One." Brutter further explained that even in earthquake-safe buildings, objects still often fall from above and the "duck (drop), cover, hold" may not protect students – especially small children – and reduce or prevent injury (Chang 2012). This scenario leads to construct an earthquake ready table that can withstand a heavy load of impact during the shake. While others ventured on other means of reducing risk before and during the shake such as the use of the cyber space and social media such as the Twitter as communication platform (Cooper *et al.* 2015), the idea of installing a resilient infrastructure inside a building has not yet been translated to physical tables in the Philippines. Thus, the study combined the school risk reduction strategy in this country with a designed desk for kindergarten that provides an alarm system when seismic activity is detected, and that automatically transforms to a much safer structure from debris and other falling objects during and after the shakes – to which students may duck and take cover.

Framework of the Study
Concepts such as disaster risk management (DRM) (DepEd-UNICEF 2008), physics, engineering and design concepts (*e.g.*, strength of materials, stability concepts), and education concepts such as usability, space aspects, orientation, and standards (Serway *et al.* 2009) contextualized the design of the "LAMESA." All these concepts form part of the conceptualization of the design of "LAMESA" as an automated desk that transforms through electronic stimuli when alarm is sounded as triggered by sensors. Development of the product and its other features highly depended on different physics, engineering, and design concepts. The entire system should also be integrated in the kindergarten curricular program as part of the risk reduction awareness campaign of the government. The DRR Resource Manual (DepEd-UNICEF 2008) also dictated other features of the design to include earthquake survival kit for emergency purposes.

Purposes of the Research
The major purpose of the study is to provide the education system with a resilient and cost effective study desk for students in kindergarten, which will serve as a warning system when earthquakes occur, as safety infrastructure for students to use and a learning tool to passive preparation of kindergarten. Specifically, the objectives are as follows:

1. Design a resilient study desk.
2. Build a resilient study desk.
3. Evaluate the design's functionality, usability, and the concept of risk reduction; and integration of the prototype to kindergarten lesson and curriculum development.

MATERIALS AND METHODS

We implemented the study in four phases. Phase 1 focused on literature search and review, brainstorming, planning, and preliminary designing of the LAMESA (Life Saving Automated "MESA" to Endure Seismic Activity) – which included inputs from partner engineer-researchers, science experts/researchers, and educator/researcher. We initiated patent search to see if duplicates are already available and to ensure that the design has the potential for patenting. Phase 2 featured the finalization of the design for a prototype automated desk. Phase 3 emphasized the construction of the prototype automated desk and testing; and the last phase focused on the validation and evaluation phase.

Participants
Convenient sampling of participants dominated the sampling procedure of the study. Engineers (civil and electronics), science experts (geologist and volcanologist), and the educator/researcher dominated the participants in the first two phases of the study that looked into the design of the prototype. Machinists, wood-workers, technicians, and end-users (educators, pupils, and the expert in DRM and school officials) joined the aforementioned set of participants of the last two phases of the study.

Research Design
Development research design directed all the processes in designing the LAMESA. Quantitative as well as qualitative methods employed in the initial phase deduced inputs for the design and the development of the prototype automated desk. These processes also orchestrated the product assessment process done by teachers, parents, engineers, and technical experts.

Phase 1: Brainstorming, Planning, and Preliminary Designing of the LAMESA
We commenced this phase by conceptualizing the study framework, the design of the automated desk, and the processes involved in the development of the automated desk and product assessment. We did an intensive literature review and patent search to trace any prints of the planned automated desk in the existing literature for product feasibility.

Phases 2 and 3: Finalization of the Design and Construction of the Prototype
We presented the preliminary design to a group of electronics experts, engineers, and machinists for initial inputs on design aspect. As soon as we captured all vital suggestions by the aforementioned group, we did the re-design and finalized the listing of materials, construction partners, details of the design, and other peripherals of the automated desk before the actual construction. This process took us about over a month to complete (see Appendix I for the detailed design). The machinist spent about two months for full completion of the automated desk.

Our partner engineers conducted the design test and calibration after the construction of the automated desk. We used the mobile shake table of the Metro Manila Development Authority (with proper paper consent and approval) to calibrate the sensors of the table to specific intensities and response systems. With the help of MMDA personnel, we placed the prototype automated desk in the shake table or the simulator (Figure 1) for calibration and testing per intensity level and per load – cumulatively increasing in both – as calibration and testing progressed. At an expected magnitude of 7.2 for the "Big One", the mobile shake table or MMDA simulator simulates seismic movement (horizontal and lateral only) through the hydraulic motion platform that produces 4.0–8.0 earthquake intensities loaded with a maximum of 5–9 persons of 1,000 kg (MMDA standard).

Figure 1. MMDA Mobile Earthquake Simulator.

In a still- or non-moving condition, we calibrated the accelerometer (installed in the prototype at a horizontal position) by measuring the peak gravitational acceleration (PGA) of the device. The calibration triggered the accelerometer to have x, y, and z as output values, which become the input in the microcontroller. Through the microcontroller's user interface, we recorded 30 samples at the still condition and at intensity 4–8.

Phase 4: Evaluation and Curriculum Integration

We conducted physical evaluation for completeness and functionality before we subjected the automated table to evaluation of its design and prototype. Invited evaluators included engineers (civil, electronics, and mechanical); geologist working with PHIVOLCS, kindergarten teacher and principal, kindergarten parent, and a district supervisor of the Department of Education. We asked these eight evaluators to rate the automated desk using a rubric (Appendix II) that includes the following criteria: construction and features, design and aesthetics, completeness of electronic parts, functionality, usability/utility, embedded physics concepts, and engineering and design concepts. Additionally, we conducted an extensive interview with three practitioners in the field of early childhood education on how the concepts of disaster risk reduction and preparedness may be integrated in the kindergarten curriculum using the prototype. We also asked them to provide a sample lesson plan or lesson guide to concretize the envisioned integration process.

Data Analysis

We analyzed our sourced data from the four phases of the study using quantitative techniques such as PGA averages, recorded response times, and ratings gathered through the use of scoring rubrics to determine the extent that the design and prototype has the qualities of a desirable automated desk for DRR. Indicators for evaluation by the stakeholders focused on the following: construction and features, design and aesthetics, completeness, related concepts, risk management, stability, efficiency, and and functionality. Additionally, we summarized and coded all qualitative data generated from comments and suggestions to support the results of quantitative analysis.

RESULTS AND DISCUSSION

LAMESA Design and Prototype

The prototype automated table featured unique designs that supported its being a tool for passive and active preparedness of our kindergartens. In fact, different earthquake tables have been developed to protect the people from possible falling debris and for simulation purposes (Table 1).

Patent search. The following are the claims, classification, keywords, International Patent Classification, and documents considered as relevant in the application for patent:

1. A life-saving kindergarten school desk during seismic activity comprising: a structural support frame, said support frame having top (1) and the middle portion, (2) said top portion is a mid-separated table top, (3) having a plurality of corner legs, (4) and adjustable center legs, (5) with synchronous lift function to form a triangular shape for debris impact reduction actuated by a plurality of actuators, (6) said middle portion having a main controller unit, (7) further comprising an accelerometer, (8) that detects seismic activity and an Arduino microcontroller, (9) triggering the plurality of actuators, and a separate storage area, (10) for food and water. Characterized in that, a separate accelerometer (11) fixedly attached to the classroom wall triggering the emergency alarm, (12) synchronous with the plurality of actuators, (6) lifting the mid-separated table top, (3) and an LCD monitor, (13) displaying the earthquake's intensity and evacuation message.

2. A life-saving kindergarten school desk during seismic activity, according to claim 1, wherein said synchronous lift function of the mid-separated table top's (3) adjustable center legs (5) extend up to 16 degrees of inclination.

3. A life-saving kindergarten school desk during seismic activity, according to claim 1, wherein the center legs (5) automatically lock itself once the plurality of actuators reached the desired height and inclination.

4. A life-saving kindergarten school desk during seismic activity, according to claim 1, wherein said desk is solidly built to avoid displacement by external forces.

Table 1. List of related studies.

Title	Authors	Findings
Earthquake Proof Table	Arthur Brutter and Ido Bruno	Made up of rectangular metal and wood for tabletop, light weight, can stand vertical impacts, light supports at the upper corner legs.
Earthquake Proof Desks and Tables	LifeGuard Structures	Engineered to support over one million pounds. Designed to withstand full or partial building collapse on any floor. The real wood exterior in a variety of sizes, styles and colors. Interior for heavily padded, including floor and ceiling. With crumple zone like the bumper system of a car. The steel ceiling protects against punctures, beams, floors, and incredibly heavy objects from above. With padded storage wedge filled with life sustaining and rescue item. Can support one person per table.
A Hybrid Fuzzy Logic – PLC-Based Controller for Earthquake Simulator System	Rennan G. Baldovino and Elmer P. Dadios	It presents an intelligent motor speed controller for an earthquake simulator using fuzzy logic algorithm developed inside a programmable logic controller environment. The desired motor speed is obtained using two fuzzy inputs – namely, the process error and the rate of process error. These fuzzy inputs are feedback data from the motor drive. Different earthquake intensities were used to test the controller's performance in real time undergoing different load variations.

International Patent Classification: E04H 9/00, E04B 1/00, A47B 2200/008, G01M 7/00

Keywords: seismic table, table for earthquake, earthquake proof table

Such search claims to identify the automated desk as best for utility model for use in the Philippines.

Physical design. Figure 2 shows the designed table structure. We used steel bars with rubber footings for the legs. We believed that steel bars would contribute a little amount of weight, but are strong enough to hold debris. The rubber footing intended to provide high frictional force between the automated table and the floor for lesser translational movements. We also designed the center legs to have an adjustable synchronous lift function that raises both sides six inches higher to form a triangular figure to cause the debris to slide down. The leg extension can lock in place. We also used stainless steel for the table top because of its high elastic strength, and we coated the table top with epoxy paint to increase the durability and decrease sliding friction between the debris and the table top. We envision that both the kind of material used for the table top and its surface structure would contribute to making any debris hitting the table top slide to support our kindergarten. We also designed the mid-section of the LAMESA as a storage bin where we can store light, food, and water. We built the bin with a sliding door for easy access for our kindergarten when they are thirsty or hungry after an earthquake.

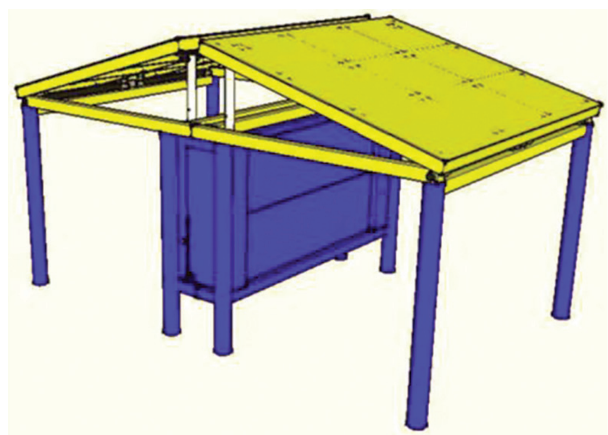

Figure 2. Design of LAMESA.

We designed the table dimensions (Figure 3) suited to our intended users (kindergarten) as follows: length of 1.22 m (48 in.), width of 0.69 m (27 in.), height of 0.57 m (22.5 in.), and tabletop thickness of 1.31 m conforming to the standard table size for kindergartens (Smith System 2018). The height of a typical kindergarten pupil (in the recipient institution) is 0.91 m (3 ft.), which ensures that our kindergartens will be able to hide under the table. For each table, four kindergartens can be shielded from debris during the shake or seismic activity. We planned to mount this automated table in the kindergarten room of the National Center to Teacher Education Laboratory School where the room capacity approximates to 30 students. The prototype automated desk has the following features

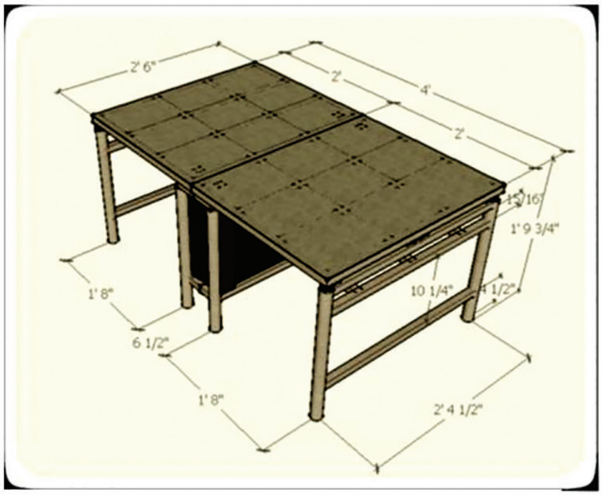

Figure 3. Dimensions of LAMESA.

specifically designed for the safety of the kindergarten during a seismic activity:

1. Can detect seismic activity through an electronic circuit
2. Automatic tabletop inclination for debris impact reduction
3. Lightweight box for LCD to display the intensity of the earthquake
4. Can carry more than 200 kg weight
5. Sound alarm to alert people around
6. Compact and yet safe seating for K pupils
7. Emergency supplies storage
8. Cannot be displaced/repositioned easily by external forces
9. Solidly built
10. With manual of operation

System design. The block diagram of the system (Figure 4) shows that the accelerometer senses the seismic activity, which will measure the x,y,and z values of the seismic movement. These measured values will be inputted to Arduino microcontroller that will simultaneously trigger the three major systems connected: 1) the movement of the actuator that will increase the table height until 16 degree of inclination is achieved; 2) the alarm system that will produce sounds to alert the person inside the classroom; and 3) the LCD display that will show the intensity level of seismic activity.

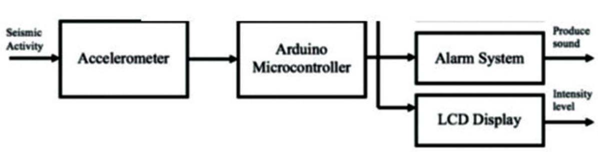

Figure 4. Block diagram of the system.

As shown in Figure 5, the main controller unit circuit used a Gizduino microcontroller embedded on top with a Wi-Fi shield in order to communicate wirelessly with its sub controller that comprises an accelerometer and a servo motor. We wired the Gizduino with two push buttons for incrementing and decrementing the threshold of vibration detection. A 16 in x 2 in LCD displays the current threshold and gives a message if evacuation is needed and a buzzer for signaling if the threshold of vibration is above normal.

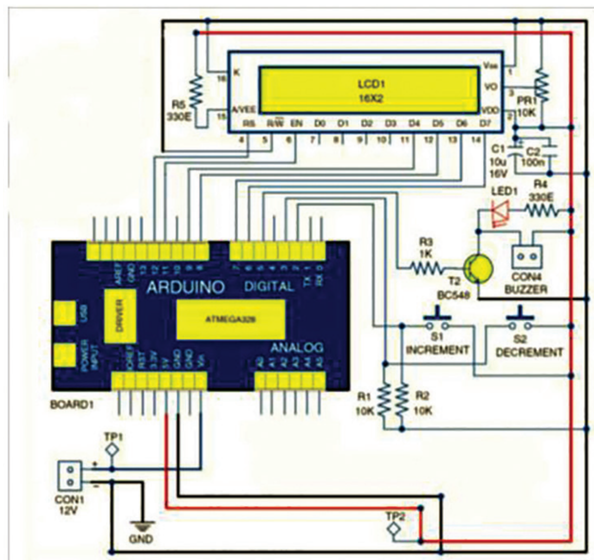

Figure 5. Main controller unit circuit.

In this study, we used ADXL345 3-Axis Digital Accelerometer (IC dimension: 3 mm x 5 mm x 1 mm), which can measure both the static and dynamic acceleration of gravity (Analog Devices 2017). It is a Gizduino version 5 with ATmega 328P, which uses the standard programming language and is a simple I/O platform (E-Gizmo) with a designed program, which we can easily implement in this device using its IDE. It has six Analog In and 14 Digital I/O and can be supplied by a 5V power supply. With its high resolution of 13 bit, the accelerator can detect even less than 1 degree of inclination. The threshold of this device can be set for detecting the presence or lack of motion. Also, it can dissipate low power because of its intelligent motion-based power management.

Software design. The program flowchart in Figure 6 shows that the initialization of the reset pin; alarm pin; and moved (x, y, z) and still values (X, Y, and Z) trigger the accelerometer to measure the x, y, and z, which become the moved values. The program compares the still values x, y, and z with that of the newly measured values, and any detected difference sets the actuator to “ON” mode.

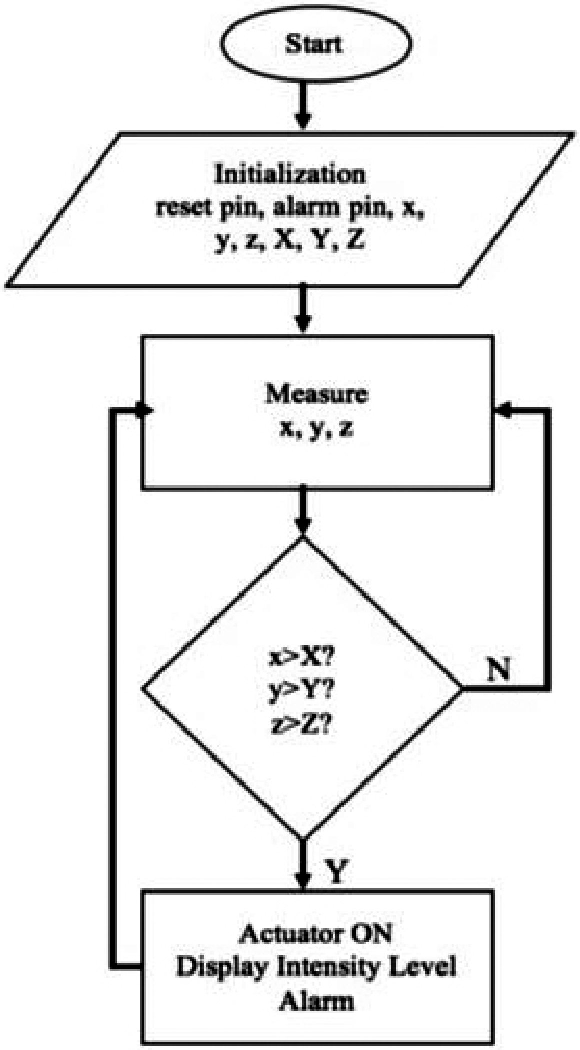

Figure 6. Program flowchart.

The actuator then moves until it reaches the desired height, which also activates the lock system. The intensity level will be displayed and the alarm will produce a buzz sound. With the same movement, the program will continue to measure the x, y, and z values until there is a change in a value as set for the threshold value.

Table 2. Summary of search.

Database	Search String	Number of Hits
EPO	Earthquake proof table	33
EPO	Table and earthquake	684
USPTO	Table and earthquake	3724
USPTO	TTL/(earthquake AND (table OR desk))	3
PATENTSCOPE	Earthquake proof table	1620
PATENTSCOPE	Table and earthquake33	377

Table 3. Documents considered as relevant.

Category	Citation of Documents, with indication, where appropriate, of the relevant pages	Relevant to Claim No.
Y*	*CN108095132A Crush Resistant Quake-proof Protective Office Table*	Claim 1
Y*	*JP2010042213 Earthquake Proof Table*	Claim 1
Y*	*KR101841260 Table Apparatus for Escape from disaster*	Claim 1

*Document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

Calibration, threshold, and response time. With the 30 samples collected at still condition and at intensity 4–8, Table 4 shows the threshold peak ground acceleration (PGA) and the computed threshold values for the three directions (x, y, z) at each intensity.

This technical test considered as standard in establishing the capability and threshold of the automated table conforms to design test and evaluation. Designers of shake tables (Prasad *et al.* 2004, Stehman 2014) also used the

Table 4. Average PGA measurements and their corresponding threshold

Intensity	Peak Ground Acceleration (PGA) (g)			Threshold (g)		
	x	y	z	x	Y	z
Still	–11.14	1.56	22.34			
4	–8.59	1.39	22.13	2.55	–0.17	–0.21
5	–9.91	0.61	22.83	1.24	–0.95	0.49
6	–10.60	1.02	22.89	0.54	–0.54	0.56
7	–11.01	1.46	22.78	0.13	–0.10	0.44
8	–8.67	3.44	22.71	2.48	1.88	0.37

same standard test to establish the standard capabilities and threshold of their shake tables in addition to the response time test.

Response time. Actual prototype testing using the MMDA Mobile Earthquake Simulator determined the response time (the time it takes the desk to transform) of the prototype. Table 5 shows the response time of the prototype at the identified intensity. We noted small variations of the response time in Intensity 4, which also registered the longest response time compared to other intensity levels. Moreover, the prototype has a fix response time for about 4 seconds.

Table 5. Response time of the prototype.

Intensity	Trial 1 (s)	Trial 2 (s)	Trial 3 (s)	Mean (s)	SD
4	7	5	5	5.67	1.15
5	4	4	4	4.00	0
6	5	4	4	4.33	0.57
7	4	4	4	4.00	0
8	3	4	6	5.00	1

Noting this characteristic feature of the prototype provides ample time to shield children from debris during an earthquake. On average, a strong earthquake that may cause debris lasts for about 30–40 seconds (GNS Science). Thus, a much lesser response time of earthquake sensors and the automated table will effectively and efficiently facilitate better "dock, cover, hold" actions of kindergartens to shield them from debris in the eventuality of a strong one.

Assessing LAMESA

We sought the help of experts in the field of engineering and geology (engineers with specialization in civil, electronics, and mechanical) and stakeholders (kindergarten teacher, principal or school head, parent, and district supervisor) to evaluate the automated desk (LAMESA) on the following criteria: features, design and aesthetics, usability, system functionality, and mechanism functionality. Feature (in the evaluation rubric) refers to the proper construction of the automated desk and the inclusion of all significant structures as specified in the design. Design and aesthetics exemplify excellent safety features for the pupils during class hours and the extent of the automated desks visual appeal. Usability pertains to the purpose of the LAMESA as a school desk and as a protective shelter during earthquakes. System functionality depicts the ability of the automated desk to detect seismic activity, display intensity of earthquake, notify people around on the occurrence of seismic activity with the sound of an alarm, maintain safety for the pupils from electrocution. Mechanism functionality denotes the capability of the tabletop to incline automatically without causing panic to the people around during emergency, the accessibility of the supply storage for the pupils during an emergency, the capability of the LAMESA to shelter at most four pupils; and the assurance that the table cannot be repositioned by external forces. Table 6 presents the results of the evaluation done by the four experts and that of the stakeholders.

Three of our experts are engineers with specialization in civil, electronics, and mechanical while one is a geologist. On the average, these experts rated the LAMESA of High Quality (HQ) in terms of its features, design and aesthetics, and mechanism functionality. They confirm that the automated table is properly constructed and has most of the features as specified. They assessed the design as very good and visually appealing with very good safety features for the pupils during class hours. The experts also noted that LAMESA exhibited all the four indicators of mechanism functionality during the simulation test. Their noteworthy feedback on the LAMESA's usability (excellent) considered the automated desk a school desk and as a protecting shelter during earthquake. Our experts' lowest rating goes to system functionality (Average Quality [AQ]) with minor areas and concerns to be addressed. The experts deemed that the LAMESA possessed all system functionality indicators, but there were very minor problems observed (see Table 7).

Table 6. Assessment by the experts and stakeholders.

Indicators	Expert's Rating				Stakeholder's Rating					
	A	B	C	D	Principal	Teacher	Parent 1	Parent 2	Parent 3	External Evaluator
Features	4	4	3	4	4	5	5	5	5	4
Design and Aesthetics	3	4	3	5	4	5	5	5	5	5
Usability	5	5	4	5	5	5	5	5	5	5
Mechanism Functionality	4	4	4	5	4	4	5	5	5	5
System Functionality	3	3	4	4						

Table 7. Recommendations for the enhancement of the design.

Indicators	Limitations (common to all indicators)	Recommendations
Features	• The classroom must be constructed with outlet (electricity) on the floor and fixed mounting for the table • Assurance for safety (*e.g.*, accident, electrocution) • Sensitivity of the electronics • Rough edges; using a tubular steel would be better • Proper wiring (not visible to the children for possibility of playing with it) • Hardness of the desk can be a possible source of accident for kids especially when they bump into it (but negligible)	• Should detect even low intensity (2–3) • Use of tubular steel for smooth feature • Inclusion of specification for power consumption, voltage ampere, *etc.* as other gadgets available in the market • Provision for cushion on table legs and horizontal support • Improvement of electrical supply chords and method of power supply to avoid possible electrocution • Installation of sound alarm for installation (on the wall of the classroom) • Provision for bigger LCD display (intensity) • Inclusion of brochures for completion • Provision for additional power supply for the project [220V AC and 12V DC (Battery)] and back up batteries in time of power shortage or blackout • Replacement of cable by royal cord • Faster response of the actuators (the faster response time, the better)
Design and Aesthetics		• Removal of sharp edges and trim all corners / smooth (curve) edges to protect child's body • Modifications on the compartment, especially the accessibility and safety features • Provision for possible use of lightweight metal for the table top (aluminum) and additional cover in the middle of the table top once activated • Inclusion of variety of colors to be more attractive to students • Inclusion of LED light (strip) must be added • Inclusion of safety reminders similar to other electrical appliances • Improvement in the design to make the table lightweight
Usability		• Has to address the concerns on safety features, particularly on electrocution • Safety features for kinder students who might play under the table in ordinary day • Need for close monitoring of the functionality of the flashlight and the expiration dates of the biscuits and water inside the "Go bag"
System Functionality		• Installation of sound alarm system and provision for indicator lamp corresponding to "on and off" operations • Improvement of electrical wiring systems / need full proof or insulated wiring / isolation from metal housing / proper wiring to lessen possible accidents • Improve electrical supply to avoid possible electrocution • Electrical cord should be installed safely (on the floor)
Mechanism Functionality		• Supply storage should be made automated (door's open and close automatic) • Modifications on the accessibility of the supply storage • Inclusion of automatic light (LED) once table inclines automatically (aside from the flashlight inside the Go bag) • Improvement of the quality of whistle/flashlights • Automation of the unit after the earthquake • Must be subjected to impact loading
Others		• Orientation to the students about the "Go bag" and the use of the first aid kit • Provision for training of students who will be using first-aid kits • Conduct of earthquake drills at least quarterly • Earthquake drills must be explained and demonstrated well • Trainings for the one that will be using the LAMESA (*e.g.*, kindergarten teachers)

Our invited stakeholders evaluated the automated desk on almost the same criteria except for system functionality. They rated the prototype as properly constructed with all the features as specified. They also believed that although the automated desk has an excellent design and is visually appealing, the prototype also provided excellent safety features for the pupils during class hours and is a very useful school desk acting as a protecting shelter during an earthquake. Lastly, our invited stakeholders rated the automated desk to have exhibited all the five indicators of mechanism functionality during the simulation test.

Overall, our invited evaluators gauged the LAMESA to be of high quality. Experts' and stakeholders' assessment provide significant information on the current condition of the automated desk in terms of the identified criteria (Dam and Siang, OECD, UC 2017). In fact, they identified several strengths as follows: able to operate as expected, reliable in times of disaster, stable and can withstand magnitude 8, sturdy and made of metal, can carry heavy objects on top, is not easily displaced by external forces, has attained its overall objective, and child-friendly in terms of size and color appropriateness. However, they also saw several items that needed improvement and suggested several recommendations for improvement (Table 7).

Significant recommendations pointed mainly to inclusion of more safety features since the major end users are kindergarten students (Kaplan Learning Center 2014, Buckman 2018). Most experts and stakeholders recommend high utility and usability of the material for proper DRR preparation (both passive and active). They also emphasized that load testing is necessary to establish the design's stability, which we considered as the target for phase 2 of the project. Proper orientation and training to end users (kindergarten teachers, students, and parents) and wide information dissemination (Dam and Siang, OECD, UC 2017) may initiate better applicability and usability of the materials. It would even help if kindergarten teachers integrate the use of such prototype in the kindergarten curriculum and consciously direct lessons on natural disaster and risk reduction and management with utilization of the prototype as a major learning aid.

Interviewed practitioners in the field presented the Philippine kindergarten curriculum (Figure 7) from which to source information on how integration of DRR and disaster preparedness concept may be directed. The outer circle of the figure corresponds to the interrelation of the learning domains dictating enactment of the curriculum. Concepts and themes in the curriculum significantly considered developmentally appropriate practices of a "five-year old" to provide holistic child development through the themes: Myself (concepts and ideas that help the learners understand himself/ herself better so that he/she will develop as an individual); My Family (concepts, ideas, and practices that guide the child to be responsible and proud of himself and his family); My School (concepts, ideas, practices, and situations that help the child understand how to be an individual and socialize with other learners, teachers, and other school personnel); My Community (concepts, ideas, practices, situations, and responsibilities that the learner should acquire and understand so that he/she will a become functional and responsive member of the community); and More Things Around Me (all other concepts, ideas, practices, situations, and responsibilities beyond themes 1 to 4, but which may be relevant to the community, culture, and interest of the learner). Our expert practitioners view the theme "Myself" as the venue for integration of the DRR and disaster preparedness. Themed as "*Pangangalaga sa Sariling Kalusugan at Kaligtasan: Naipapakita sa simpleng kahandaan sa panahon ng sakuna: lindol, baha, sunog, atbp.*" (Self-care and protecting the self from harm: Showing simple readiness during calamities: earthquakes, flood, fire, *etc.*), they envisioned to use the prototype as they have planned in the sample lesson (Appendix III) to fully cover the wide range of passive disaster preparedness to complement active disaster preparedness.

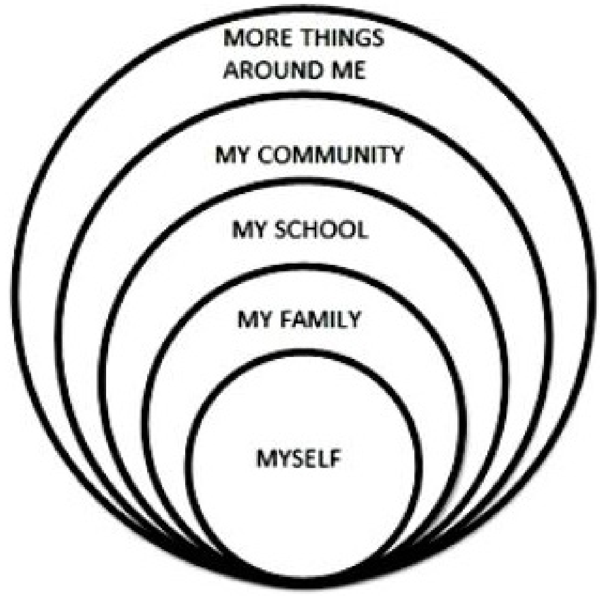

Figure 7. Kindergarten curriculum.

DISCUSSION

The study aimed to provide the education system with a resilient study desk for students in the kindergarten. This automated study desk intends to serve as a warning system when earthquakes occur, as safety infrastructure for students to use, and as a learning tool to passive disaster preparation of kindergarten.

The developed prototype features vital structures attuned to the aims of the study. The physical design highlights the use of lightweight but strong materials (high elasticity and material strength) to provide strong protection to the intended end-users. Additionally, the desk features low-friction tabletop to provide sliding mechanisms for falling debris, storage bin for food and utility, and precautionary security such as rubber footing (Prasad *et al.* 2004, Stehman 2014). The system design (which dissipates low power) ensures the efficiency of the three major systems: 1) the movement of the actuator that will increase the table height until 16 degree of inclination is achieved; 2) the alarm system that will produce sounds to alert the person inside the classroom; and 3) the LCD display connected to the device known as the accelerometer, which senses the seismic activity will show the intensity level of the seismic activity. Programming language used for the software design ensures proper flow of inputs for the table's efficient and effective sensing, quick response, and proper and safe transformation during a seismic activity. Features and structures of the designed automated desk fit the specifications of a kindergarten desk, provide safety for kindergarten students during a seismic activity with a fixed response time of about four seconds (lesser than the usual 30–40 second for a building to collapse), and is excellently-rated by experts and stakeholders. However, several items on the usability, features, design, and mechanism functionality needed some improvement before full implementation and use.

Significantly, the prototype concretizes both components of disaster preparedness (passive and active) (Okada 2013). For active disaster preparedness, the prototype serves as protective roofing to (at most) four kindergartens to shelter them from falling debris in the event of a strong seismic activity. Additionally, the provision for "go bags," water, and food in the storage bin provides possible sustenance in cases of prolonged enclosure inside the prototype in the event of building collapse or heavy damage. Similarly, inclusion and integration of the concepts of DRR in the kindergarten curriculum may highlight passive disaster preparedness. In fact, weaving the prototype; the kindergarten curriculum – even the required medium of instruction (mother tongue, first language, or home language) – and teacher's enactment of the curriculum insinuate a high probability of success in the aspect of passive disaster preparedness, thus exuding a holistic approach to DRR and disaster preparedness in the early childhood level.

CONCLUSION

This effort towards holistic disaster preparedness package may underscore adoption and influence of citizen science *i.e.*, citizens observing natural events and characteristics to genuine revolution in science that democratizes the important social role of learning about the world around us, in the curriculum (McEver *et al.* 2007, Muller and Tippins 2011). Apparently, the visible partnership of trained scientists (engineers, programmers, and science specialists) and the community (parents, teachers, and learners) deduced the concept and concretization of disaster preparedness through the prototype desk. Symbolically, the automated desk pronounces an initiative to citizen science by incorporating citizen science into the curriculum – combining traditional (teaching and learning practices) and innovative (integrating DRR and disaster preparedness) methods (Shah and Martinez 2015) in a kindergarten lesson using the prototype – to provide practical experience of science emphasizing the recognition and use of a logical and systematics approach to solve problems (disaster brought about by natural calamity) affecting the community.

ACKNOWLEDGMENT

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All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.Informed consent was obtained from all individual participants included in the study.

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Appendix I. Design details.

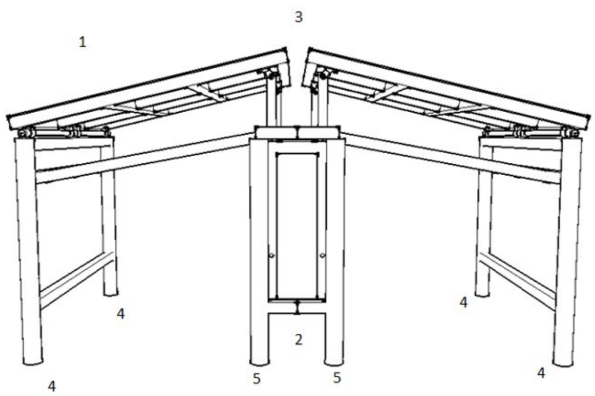

Fig. 1. Makers: I.C. Valenzuela, N.M. Arago, N.Z. Jovero, T.F. Figueroa, E.L.R. Abulon, and M.P.E. Morales.

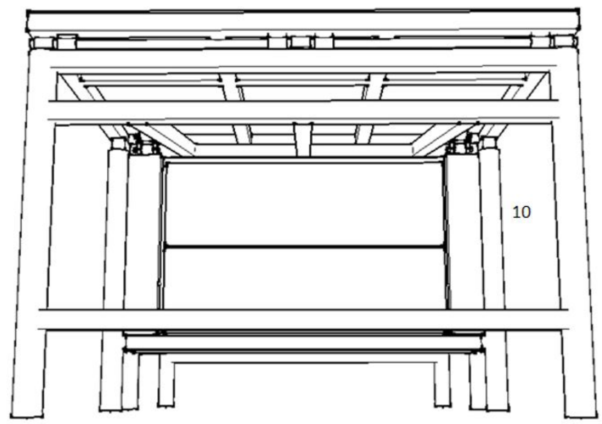

Fig. 3. Makers: I.C. Valenzuela, N.M. Arago, N.Z. Jovero, T.F. Figueroa, E.L.R. Abulon, and M.P.E. Morales.

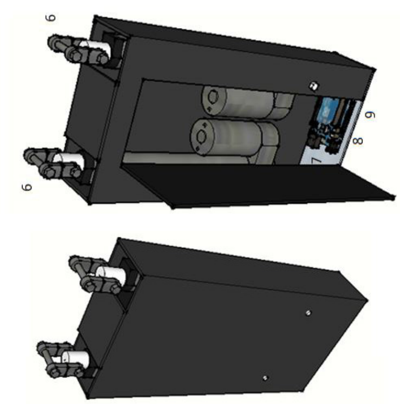

Fig. 2. Makers: I.C. Valenzuela, N.M. Arago, N.Z. Jovero, T.F. Figueroa, E.L.R. Abulon, and M.P.E. Morales.

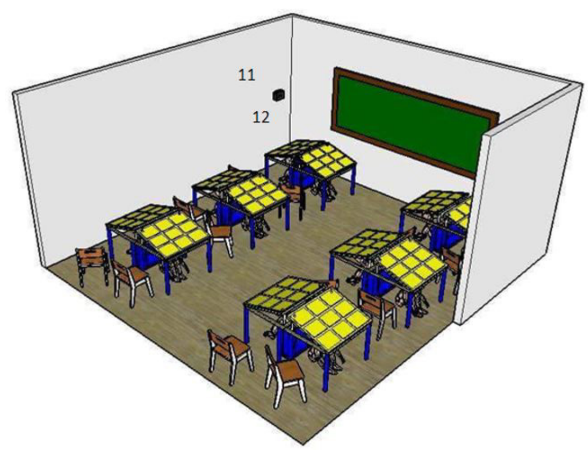

Fig. 4. Makers: I.C. Valenzuela, N.M. Arago, N.Z. Jovero, T.F. Figueroa, E.L.R. Abulon, and M.P.E. Morales.

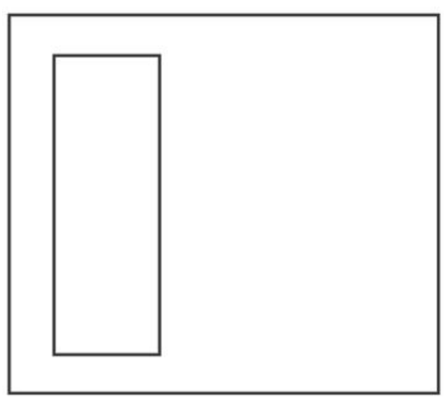

Fig. 5. Makers: I.C. Valenzuela, N.M. Arago, N.Z. Jovero, T.F. Figueroa, E.L.R. Abulon, and M.P.E. Morales.

Appendix II. Scoring rubric for the evaluation of the "LAMESA" (for the experts in disaster risk management).

We are interested in knowing the extent to which you believe or think that the LAMESA (a prototype working table/desk) has the qualities of a kindergarten class' desk that would protect or reduce risk in the event of an earthquake. There is no right or wrong answer. Please use the scoring rubric based on your evaluation of the qualities of the prototype table. Provide your scores for each of the indicators on the space provided.

Indicators	**Quality**				
	Excellent Quality (5)	**High Quality (4)**	**Average Quality (3)**	**Low Quality (2)**	**Poor Quality (1)**
A. ***Features (All features as exhibited in Annex A)*** Score __________	The LAMESA is properly constructed and has all the features as specified in Annex A.	The LAMESA is properly constructed and has most of the features as specified in Annex A.	The LAMESA is properly constructed but lacks some of the features as specified in Annex A.	The LAMESA is not properly constructed and lacks many of the features as specified in Annex A.	The LAMESA is poorly constructed and lacks the essential features as specified in Annex A.
For a rating of 4 and below, what other features should be in the prototype?					
B. ***Design and Aesthetics (The Design has visual appeal and safety features for the pupils)*** Score __________	The LAMESA has excellent design and is visually appealing; the design provides excellent safety features (*e.g.*, smooth edges and reasonable size and height) for the pupils during class hours.	The LAMESA has very good design and is visually appealing; the design provides very good safety features (*e.g.*, smooth edges and reasonable size and height) for the pupils during class hours.	The LAMESA has a good design and is visually appealing; the design provides e good safety features (*e.g.*, smooth edges and reasonable size and height) for the pupils during class hours.	The LAMESA has a poor design and has limited visual appeal; the design has limited safety features (*e.g.*, smooth edges and reasonable size and height) for the pupils during class hours.	The LAMESA has a poor design and has no visual appeal; the design has poor safety features (*e.g.*, smooth edges and reasonable size and height) for the pupils during class hours.
For a rating of 4 and below, what would you suggest that would improve the design and aesthetics?					
C. ***Usability (purpose of the table as a school desk and as a protecting shelter during earthquakes)*** Score __________	The LAMESA is very highly useful as a school desk and as a protecting shelter during earthquake.	The LAMESA is highly useful as a school desk and as a protecting shelter during earthquake.	The LAMESA is useful as a school desk and as a protecting shelter during earthquake but needs some enhancement.	The LAMESA has limited usability as a school desk and as a protecting shelter during earthquake and major enhancement is needed.	The LAMESA does not appear to be a useful school desk and as a protecting shelter during earthquake.
For a rating of 4 and below, what specific aspects should be enhanced to increase its usability?					

D. ***System Functionality*** • ***The system can detect seismic activity (intensity 4–8) as per MMDA simulator capacity;*** • ***The system can display of intensity of earthquake (Ref: MMDA simulator);*** • ***The system can to notify people around about the occurrence of seismic activity with the sound of an alarm; and*** • ***The system is safe from electrocution (based on wirings).*** Score __________	The LAMESA possesses all the system functionality indicators and it was observed to function very well during the simulation test.	The LAMESA possesses all system functionality indicators and it is observed to function well enough during the simulation test.	The LAMESA possesses all system functionality indicators but there were very minor problem/s observed.	The LAMESA possesses all system functionality indicators but there were minor problem/s observed.	The LAMESA possesses all system functionality indicators but there were major problem/s observed.
For a rating of 3 and below, what other specific problems observed in the LAMESA's system functionality?					
E. ***Mechanism Functionality*** • ***The tabletop has the capacity to incline automatically;*** • ***The inclination of the tabletop cannot cause panic to the people around during emergency;*** • ***The supply storage is easily accessible for the pupils during an emergency;*** • ***When the tabletop is inclined, the table can shelter four (4) pupils at the most; and*** • ***The table cannot be repositioned easily by external forces.*** Score __________	The LAMESA exhibited all the five (5) indicators of mechanism functionality during the simulation test.	The LAMESA exhibited only four (4) indicators of mechanism functionality during the simulation test.	The LAMESA exhibited only three (3) indicators of mechanism functionality during the simulation test.	The LAMESA exhibited only two (2) indicators of mechanism functionality during the simulation test.	The LAMESA exhibited only one indicator of mechanism functionality during the simulation test.
For a rating of 4 and below, what other specific problems observed in the LAMESA's mechanism functionality?					

Please provide your comments/ observations on the following aspects of the LAMESA:

1. Strengths

2. Limitations

3. Recommendations for improvement of the LAMESA

Name of Evaluator_______________________Position ___________________________

Affiliation____

Signature ______________________________ Date ____________________________

Appendix III. Sample lesson plan to integrate the prototype.

I. Objectives

At the end of the lesson, the students should be able to:

a. Learn the basic protocol during specific calamities.
b. Recognize self-worth by taking care of themselves during calamities; and
c. Enumerate ways on how to survive during calamities.

II. Subject Matter

a. Content Focus: "I can take care of myself!"
b. Message: Showing simple readiness during calamities: earthquake, flood, fire, *etc.*
c. Materials: Video presentation, the LAMESA, pictures, worksheets
d. References: _Standards and Competencies for Five-Year-Old Filipino (Kindergarten Curriculum Guide)

III. Learning Activities

A. **Presentation**

The teacher will show students videos different calamities such as fire, floods, earthquake and others. She will ask them if they already experienced those and ask them what they did to protect themselves during those calamities.

B. **Discussion**

The teacher will discuss their answers and will ask them, how they can take care of themselves during those times. The teacher will show pictures of example of ways of protecting themselves during those calamities. The teacher will show them the "LAMESA." She will show and model to the students on how to use the "LAMESA." The teacher will discuss the features of "LAMESA" and will call some students practice the "dock-cover-hold" position under the "LAMESA".

C. **Guided Exercises**

The teacher will paste pictures on the board. Column A will display pictures of different calamities while column B will be composed of pictures that will show things people should do during those calamities. The students will connect those calamities using strings to the appropriate action you need to do during those calamities.

D. **Evaluation**

The teacher will provide a worksheet where students can draw about the calamities that they already experience before.


Name:
Date:
I already experienced......

E. **Application**

The teacher will group the students into five groups.

Group 1 – Color the Big picture of "Lamesa" and will write how to use it at the back of the cartolina.
Group 2 – The students will arrange the puzzle picture of "LAMESA" then write when to use it at the back of the puzzle.
Group 3 – The students will take down notes what to do to save themselves during earthquake.
Group 4 – The students will list all the calamities that teacher discussed earlier.
Group 5 – The teacher will give them a picture of a "Go Bag," then the students will draw there things they want to put inside of it to be able to survive during earthquake.