HyDi: Hydrometeorological Disaster Preparedness Simulator

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Abstract: The Philippines recently implemented the Kinder-to-12 (K-12) education system that now offers a Disaster Readiness and Risk Reduction (DRRR) course. The study considers the Learning gaps present in the delivery of content for the DRRR course, specifically the Hydrometeorological disasters topic, offered in the De La Salle University - Integrated School. One of the gaps identified was that students were unable to experience the disasters first-hand in the current Learning environment. This prevents them from testing the various actions and making potentially critical decisions when an actual disaster occurs. Another gap identified was that students were unable to categorize what things and/or places are safe or potentially dangerous in their environment when a disaster happens since there are different factors that may come into play during these times. The study proposes that a simulated Learning environment through Virtual Reality, where students are immersed in different Hydrometeorological disaster scenarios, allowing them to perform the appropriate safety measures as a solution to the identified gaps. The Virtual Reality simulator was developed with Unity for Android, which deployed various Hydrometeorological scenarios, designed to parallel the Philippine context.

Keywords: simulation, virtual reality, disaster preparedness, k-12, learning environments

1. Introduction

The Philippines is visited by approximately twenty typhoons every year. Out of the yearly typhoons, historically, five were very destructive (Asian Disaster Reduction Center, n.d.). Among the destructive typhoons, Typhoon Yolanda which "would be the country's deadliest storm ever" (Brown, 2013), had 6,300 deaths, 28,688 injured and 1,062 missing reports which totaled to 36,050 casualties (National Disaster Risk Reduction Management Council, 2013). To mitigate such future instances, a National Disaster Risk Reduction and Management Plan (NDRRMP) was created by the Philippine government, which is effective until 2028, that highlights the importance of mainstream Disaster Risk Reduction and Management (DRRM) in the development process. The Department of Education (DepEd), along with the integration of the recent Kinder-to-12 (K-12) program, have current policies tailored towards "institutionalizing the mainstreaming of DRRM in the Philippine Education" (Berse, 2015). This would allow students to be informed and knowledgeable about disasters so that they would know what to do before, during, and after a calamity, apart from traditional television and radio announcements.

DRRM is taught in the K-12 curriculum and is introduced during Grade 12 of a student's Senior High School year. In the current Learning environment, students do role play to act out the appropriate measures for the disaster assigned to them. However, the crucial *'during a disaster'* part is where problems arise because students are incapable of experiencing the scenarios where the safety measures can be applied to, because certain elements need to be present in a disaster, specifically Hydrometeorological ones. The students do not get to simulate many on-the-spot decision making during a disaster, since scenes are already predetermined when role playing; they do not get to experience the full effects of the safety measures they performed or choices they make, because in role play the presence of actual danger, like getting severely injured or possibly dying, along with the pressure that comes with encountering disaster is not present. Examples of elements that are essential in a Hydrometeorological disaster, but not present in a role play, are the presence of rain, thunder, scenario, can trigger the decision-making process of the learners. Aside from this, presence of time pressure, the possibility of different outcomes, and the chance that an event in a scenario may be overlooked are also not considered when students do role play.

Another problem that was identified is that in a disaster situation, students are unable to categorize which things are considered safe or potentially dangerous in their environment because there are different factors that may come into play. Examples of these factors that can affect the decision of students include the current situation - heaviness of rain, strength of wind, potential of flooding; condition of the student - (prepared, stable, or wounded); condition of the environment – (architecture of the house, road structure and features, community preparedness; available and unavailable resources); all of which can contribute to the outcome in a scenario that affects the situation of the learner.

2. Related Work

Local communities, local government and other locally situated development actors have the greatest pressure and have the most involvement for the DRRM to be successful (Fajardo, 2013). Several studies have shown the importance of early engagement of the youth when it comes to planning and preparedness efforts for disasters (Khorram-Manesh, 2017). Thus, it makes sense to integrate disaster preparedness in education. Supplementing the existing methods in the current Disaster Preparedness subject, another tool that can be integrated as another method of transferring knowledge is through “Learning by Doing” (Khorram-Manesh, 2017). An example of this method is a simulation exercise in which the subjects may be exposed to various scenarios while creating a sense of security and safety which allows them to make multiple mistakes without risking their safety (Khorram-Manesh, 2015). Using Virtual Reality (VR) in education has proved its effectiveness through several studies (Pantelidis, 2010). The advantages of VR drills over other alternatives are significant for both training and assessment. Immersive, repetitive practice in the content domain is a well-established method for mastering knowledge, skills, and affective control to the extent that they are less susceptible to external stressors leading to dissonance. Additionally, VR supports the repeatability, consistency, and feasibility of routine on-demand training that allows learners to participate as needed (Andreatta, et al., 2010).

There are several works that investigated using VR in the field of Disaster Management as well. Training for real world disaster scenarios that focus on decision making under stress was developed in the Pandora Program (Mackinnon, et al., 2013). It allowed for certain Gold Commanders; senior executives who manage crisis situations; to undergo simulations with various inputs that change the scenarios to apply different amounts of stress on the trainees. This was used to see how trainees decide under pressure, potentially affecting positive change in their decision making and strategy formulation. Another project that looked into VR in Disaster Management is a mobile serious game called MAGNITUDE (Wahyudin & Hasegawa, 2015). They presented a study which looked at a Disaster volunteer’s awareness on several ethical issues in the areas of Disaster response work. By looking at two kinds of users, the experienced and inexperienced, they were able to show that those who were inexperienced were less likely to exhibit awareness of ethical issues in Disaster work. It was important to note that the inexperienced volunteers were usually the first to respond to Disaster work as spontaneous volunteers. Lastly, the *Code Red: Triage* serious game was proposed to test a player’s mental structure in the context of Crisis management. (van der Spek, Wouters, & van Oostendorp, 2011). The study also focused on developing guidelines in development of serious games and instruction.

Looking at the literature, we can see that there are several studies looking into various aspects of Disaster Management, be it in the training for executives, volunteers or, the people themselves. Considering this, the researchers saw a need to look further into training potential disaster victims in relation to the problems that were seen in the current situation in the K-12 curriculum, with respect to the greater body of knowledge in VR simulators in Disaster Management.

3. Methodology

3.1. Data Gathering

The Learning gaps that were identified needed to be verified by Disaster Preparedness educators. Jenibel Paray and Mark Sanchez, two DRRR teachers from De La Salle University - Integrated School, were interviewed to verify the Learning gaps found, and were asked to identify other Learning gaps that were not considered during project conception. Two interviews were done, which verified the researchers' Learning gaps, and provided an overview of the classroom setup. According to the teachers, the common approach to teaching DRRR involved role play, and traditional instruction.

3.2. Instructional Design

To resolve the Learning gaps identified, the researchers developed a Simulated Learning Environment (SLE) through Virtual Reality. Instructional Design was created first, supported by the concept of Simulation-Based Learning, a Learning Theory, which replaces and amplifies real experiences with guided ones that replicate substantial aspects of the real world (Lateef, 2010). A Theoretical Framework was developed to guide the flow of content, where additional Learning theories (Scenario-Based Learning, Problem-Based Learning, and Multimedia Learning) were implemented to maximize a student's learning (Figure 1).

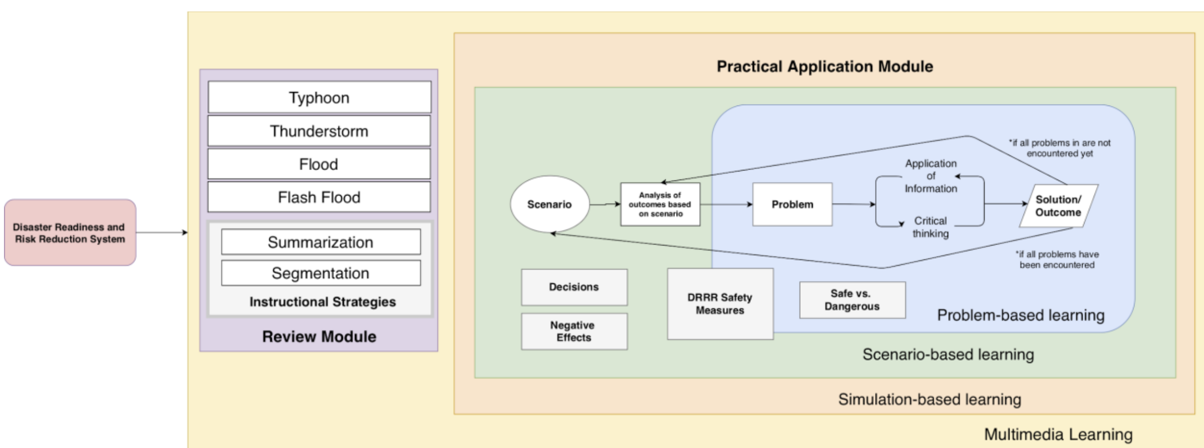

Figure 1. Theoretical Framework used for the study

In the Framework, Simulation-based learning allowed the students to be "immersed" in a disaster as if it were in the real world. Through simulations, a platform that provides repetitive practice allowed students to learn and relearn the safety measures needed to improve procedures or skills needed, creating a stronger learning environment than passive instructions. Scenario-based and Problem-based learning contributed to the SLE through contextualized storylines combined with problems where DRRR knowledge is integrated, to find the best solutions to survive the disaster. This also created a *"moment of need"* feeling for the students.

To be able to create the SLE, the design of the scenarios and the set of decisions that a student will make were then mapped. During this phase, past disasters (within the last five to ten years), that were documented (either on paper or camera) and made available publicly, were used as a basis for the creation of each simulated scenario. Likewise, each example does not reflect one specific disaster alone. Rather, these are based on several events that transpired when those types of disasters happened.

The decision-making process in the SLE is based on a combination of the different safety measures taught to the students, and the actions of various people as seen and read from their documented experience with Hydrometeorological disaster. Ultimately, the researchers made it a point that each presented choice of action in the simulation correspond to the most rational thing that a person can do when exposed to a certain disaster.

With the Instructional Design in place, various Hydrometeorological disaster scenarios (Typhoon, Flood, Flash Flood, and Thunderstorms) were then mapped, where students can be immersed in the disaster, mimicking the real world, in a safe and controlled environment without exposing them to any potential risks and danger. An effective simulation is designed based on the needs of the students and should include multiple scenarios where they can practice making strategic decisions on their own (Salas, Wildman & Piccolo, 2009). The disaster scenarios progress through the different decisions the student makes, affecting their survival capabilities in the simulation. Since there are infinite decisions that can be made given a scenario, choices or actions provided for the students are focused and aligned on different precautionary measures that can be performed before, during, and after a disaster. Each decision will have a different effect on the student's health and/or environment throughout the simulation. Moreover, risks are incorporated in the choices that the students take, which could impact future events or choices. These risks signify the exposure of the student to potential dangers caused by the choices made, regardless if it will result to a negative outcome in the scenario or not. These will not be explicitly shown to the student until after a decision has been made, or after the scenario. This is to allow the students to perform actions on their own volition, rather than the simulation forcing them to make good decisions.

Risks throughout the simulation are classified into low, moderate, and high risks. Low risks are ideally the safe choices that will have a low possibility of endangering the student. Moderate risks are choices that will most likely endanger the student. High risks are the critical choices that when made, exposes the student to imminent danger. In Simulation-based learning, it is crucial that as student engage in the decision-making process, as they are given concrete feedback regarding the appropriateness of their choices (Salas, Wildman & Piccolo, 2009). With this, an analysis of what happened is provided by the end of each scenario that explains why the student was able, or unable to survive the disaster based on the risks he took throughout the simulation.

3.3. Prototype

The SLE was developed using Unity, which was exported as an extractable application package (APK) and can run on Android smartphones using the Cardboard Application by Google. To run the application, the smartphone to be used needs to have a gyroscope to allow camera movement. Additionally, assets were downloaded from the Asset Store for free, under the Creative Commons License, or developed by the researchers themselves.

The prototype consists of three sections: The Review module, the Simulation (practical application) module, and the Assessment module. The Review module consists of materials that go through various disasters and how to identify what a scenario is (Figure 2). The Practical application module is segmented into six different sub-modules covering the following topics: Typhoon, Flood, Flash Flood, Thunderstorms, and two additional simulations of combined disasters such as Typhoon-Flood, and Thunderstorm-Flash Flood. The Assessment module was intended to allow the students to test if they can identify the type disaster in the simulation that happened.

Figure 2. Screenshot of the review module in the system

Development involved the construction of the SLE where the students are going to be immersed. Based on the scenarios created, the researchers made a layout of what each environment would look like (Figure 3). After which, the interactive components of the simulated scenario were laid out (Figure 4). These include the buttons that users can base their decision or action on when in the simulation. Since there can be one to three segments in the simulation - before, during, and after the disaster - the interactive elements will depend on what segment in the simulation they are currently in. Since each button has an equal effect to the simulation, animations, audio cues, and additional assets and displays were then included (Figure 5). The effects or consequences that are incorporated per simulation were gathered through data on past Hydrometeorological disaster reports in the Philippines. All causes of casualties were ranked according to number of occurrences and applied to the simulation accordingly. Once a decision has been made, the student can no longer access the other options, and the simulation will progress according to the decision made. To finish the rest of the simulation, elements in the environment that are unnecessary but still important were added, making it as immersive as possible.

Figure 3. Screenshot of the environment in the actual simulation

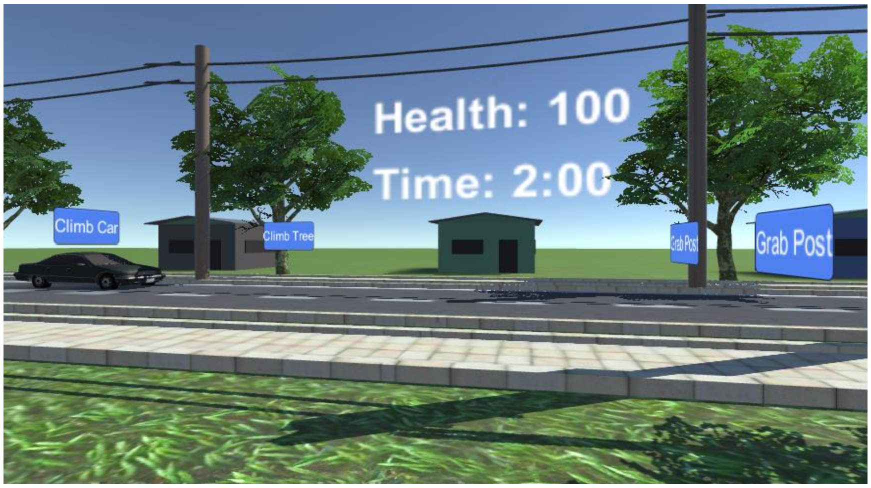

Figure 4. Screenshot of the interactive components in the actual simulation

Figure 5. Screenshot of an animation in the actual simulation

After each simulation, an assessment will be presented to the students, still using the system, to gauge if they understood and was able to identify the type of Hydrometeorological disaster they just finished simulating (Figure 6). To conclude the simulation, a summary of what actions were made in the simulation are displayed, highlighting the decisions that resulted to low, moderate, and/or high risks that will serve as a self-assessment to the students (Figure 7). The level of each risk was consulted and verified with the DRRR teachers with careful considerations on: (a) the layout of the environment and placement of assets, and (b) the effect of the action to the player or the simulation.

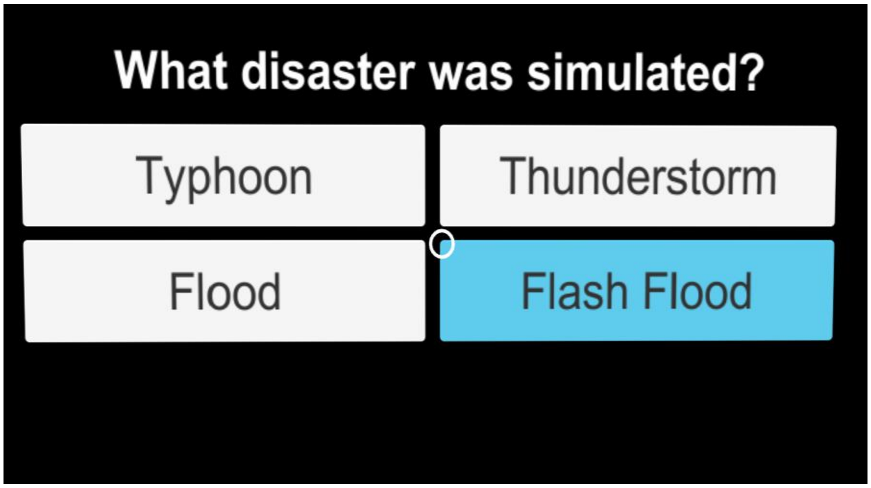

Figure 6. Screenshot of the assessment module

Figure 7. Screenshot of the assessment feedback in the system

3.4. User Acceptance Testing

Data was gathered from 24 Senior High School participants during the two rounds of User Acceptance Testing conducted on July 20, 2018, and August 10, 2018. A pre-screening method was conducted to determine if the students are qualified to participate in the testing. This was done because the simulation involves disaster scenarios and effects that may trigger traumatic experiences and distress to participants who have anxiety disorders. The Generalized Anxiety Disorder 7-item (GAD-7) scale was used as a pre-screening tool, where students answer a 7-item questionnaire to identify probable cases of GAD (Spitzer, Kroenke, Williams & Löwe, 2006). Students who acquired a total score of ten or above, though their parents have signed a consent form, were not allowed to participate in the testing because they might resemble moderate to severe symptoms of anxiety disorder.

The participants of the testing rounds were asked to answer a questionnaire after using the simulator. The five categories that were highlighted in the questionnaire were System Functionality, the Review Module, the Simulation proper, the Assessment post-simulation, and the Overall Experience. Answers were gathered through a 5-point Likert scale, where 1 was "Strongly Disagree," and 5 as "Strongly Agree." Also, open ended questions regarding the simulator were included to get qualitative data as well. Table 1 shows the overall and averaged results from multiple questions from each category. The result data from the tests conducted, and each category is measured in percentile scores to quantify the data that was collected.

Table 1

Percentile score of the User Acceptance Testing responses

Criteria	Percentile Score
System Functionality	77.15%
Review Module	87.10%
Simulation	92.53%
Assessment	96.36%
Overall Experience	78.84%

It is indicated above, the students found the Hydrometeorological Disaster Preparedness Simulator to be effective, such that its functionalities and navigations are working, and the students saw the value of the simulations in relation to their DRRR subject, although it still needs improvements in various areas such as system response.

Upon analysis of the qualitative feedback, one of the main strengths of the system, according to the users, was its immersiveness. The system was able to deliver a near-lifelike experience where the students saw the disasters first-hand and their effects. The weaknesses of the system, however, focused more on certain usability aspects. Some students have stated that they got dizzy after using the system for a while, while others commented that certain buttons were not visible enough causing confusions on certain portions of the simulations.

The participants have expressed that the system is not only relevant with what is taught in their DRRR class but also effective in its means of delivering an improved Learning experience in dealing with disaster situations and applying the necessary safety measures involved. They have also expressed their desire to use the system and experience more disaster simulations once it is released.

4. Further Study

4.1. Further Research and Development

The system was tested with Senior High School students who have no physical, mental, and/or health issues. Further research can be done to understand how different users will react to the system, more specifically, users from different age groups, different grade levels, and different levels of knowledge in the use of technology. These would all contribute to launching the system for the public, as additional means for people to learn disasters, outside of traditional media (television and radio) that is encountered today.

Implementation of the system outside Metro Manila might also yield different results since the scenarios designed had design considerations from urban communities. With this regard, the implementation of the system in this rural context might yield different results compared to the results gathered from De La Salle University - Integrated School Senior High School students.

Further instructional and technical development can be done for the system. All the scenarios simulated focused on short-term scenarios. The researchers believe that simulating the medium to long-term effects of disasters by integrating new or advanced levels to the current versions can be useful to visualize what happens in a disaster scenario beyond the short-term. Technical issues can be investigated further, as optimization issues can be addressed by using code and features not available using open source code and media.

AB testing would be conducted to see how well the simulation would improve a class's performance. A control class under Ms. Paray would use traditional role playing, while Mr. Sanchez's class would use the VR simulation. A standard assessment would then be issued to both classes after the activity to see if the simulation would provide a better result, as well as experience, to the students involved.

4.2. Implementation

The project will be rolled out in Senior High School DRRR classes in DLSU - Integrated School under the supervision of Mr. Sanchez and Ms. Paray. After each Hydrometeorological topic stated in the syllabus, the corresponding simulation will be used by the students. The system was developed in line with the DLSU - Integrated School DRRM curriculum in mind, which is based off the Department of Education's (DepED) curriculum design. The simulation would replace the role play activity in the DRRR classes. Students would be monitored by the teacher six at a time, a number mirroring the members of a role play group. It contributes to three out of five learning competencies that are defined in the DRRR Teaching Guide released by the Commission on Higher Education. These competencies are: (a) distinguish and differentiate among and between different Hydrometeorological disasters, (b) recognize signs of impending hydrometeorological hazards, and (c) apply appropriate measures / interventions before, during, and after Hydrometeorological disasters.

Teachers would then use the post-simulation appraisal to see the progress and decision-making of each student, and provide the necessary intervention needed to further a student's knowledge and understanding. It is projected that the Hydrometeorological simulation be fully implemented in the DRRR course of DLSU in the following terms, pending administrative and technical requirements.

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