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More information

This project was supported through the Ako Aotearoa National Project Fund 2012. More information and a summary report is available at www.akoaotearoa.ac.nz/improving-science-communication-skills.

This project also produced a detailed instructor's manual which walks educators through the process of organising and implementing a complex role-play during a simulated earthquake event. This manual, Communicate the Quake, can be found here: http://serc.carleton.edu/introgeo/roleplaying/examples/143264.html

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Acronyms used

ANOVA	Analysis of Variance
CDEM	Civil Defence and Emergency Management
CIMS	Coordinated Incident Management System
CE	Communication Experience (instrument)
EOC	Emergency Operations Centre
ENG	Engineering
EM	Emergency Management
HAZM	Hazard and Disaster Management
NZ	New Zealand
PCC	Perceptions of Crisis Communication (instrument)
PIM	Public Information Management
SAG	Science Advisory Group
SBRP	Scenario-Based Role-Play
SPCC	Self-Perceived Communication Competence (instrument)
UC	University of Canterbury

Summary

We report on a two-year project to develop, validate and evaluate a complex scenario-based role-play (SBRP) exercise. Using an earthquake scenario, our aim was to assist participants (students in geology, engineering, and hazard and disaster management, as well as emergency management professionals) to improve their science communication skills.

The project was split into two phases. The first phase focused on the development of the scenario itself, and the communication tasks for the participants. This phase comprised iterations 0-3 (n=30 students, n=11 instructors) and we used a mixture of classroom observations, and student and instructor feedback to make iterative improvements to optimise the flow and look-and-feel of the SBRP. In the second phase of the study (iterations 4-6; n=44), we developed and validated two instruments to measure communication experience (CE) and perceptions of crisis communication (PCC). Combined with an existing instrument measuring communication confidence (SPCC), we were able to assess a variety of factors influencing communication performance. For the scenario, we chose an earthquake event affecting Greymouth, on the South Island of New Zealand; which is affected by local seismicity and regional seismicity from a possible Alpine Fault event. Supportive technology was also developed. This focused on providing supporting scientific and infrastructure data, as well as modern communication tools, delivered through Google Earth, file sharing, and social media.

SBRP participants are assigned to realistic roles and responsibilities (e.g., the Group Controller, GNS Seismologist, or Public Information Manager) and work within realistic teams modelled after the New Zealand Civil Defence and Emergency Management organisational protocols and structures. These are the Science Advisory Group (SAG) which provides science advice, and the Civil Defence and Emergency Management (CDEM) team which manages the crisis. Participants experience several authentic crisis communication tasks: town-hall meetings, developing an information pamphlet, media releases, radio bulletins, a press conference, a panel discussion and a debrief. Results from phase one showed that the final SBRP was a robust and flexible tool to meet a variety of learning goals.

Using the SPCC, we found that students from the US had statistically higher pre-scores than NZ students (78% versus 69%, unpaired t-test, $t=2.39$, $p=0.03$). This indicates that a student's background may influence their communication confidence. Overall (on average) experience resulted in positive changes with most students achieving positive changes with a mean change of 2.6 ± 4.3. A paired t-test of pre- and post-SPCC scores resulted in statistically significant differences ($t=-3.00$, $p=0.006$) indicating that our SBRP is successful at positive changes in communication confidence. These changes were independent of pre-score, meaning that the SBRP is effective in changing confidence levels regardless of previous levels of confidence. The largest positive shifts are observed in the public speaking, meeting, and stranger (i.e., unknown member of the public) categories of the instrument, which is encouraging as these dimensions are explicitly emphasised in the SBRP.

Using the PCC, we compared participants' perceptions of crisis communication to those of experts (i.e., academics, emergency managers, and science communicators). Participants showed statistically significant positive shifts (i.e. more agreement with

expert perceptions; paired t-test comparing pre- and post-scores; $t=-7.76$, $p<0.001$, Cohen's $d=-1.00$). In addition, one group achieved higher changes than others (iteration 4 participants mean change $=10.7 \pm 6.0$; iteration 6 participants mean change $= 5.7\pm 3.4$; unpaired t-test, $t=2.38$, $p=0.03$; Cohen's $d=1.02$). Several factors appeared to influence the amount of changes achieved, such as nationality, their year of degree programme, and the team (i.e., CDEM versus. SAG) the participants were in during the SBRP.

Analysis of the individual statements on the PCC (49 in total) showed that there were items in which most student groups agreed with experts ('high perceptions') and others which they disagreed with experts ('low perceptions'). More importantly there were several topics which experts struggled with (i.e., resulted in predominantly 'neutral' responses, but with distributions leaning more towards agree or disagree) that also resulted in mixed and low perceptions from the student participants. Notably, the topics of: comprehensiveness, showing the scientist's emotions, political influence/agenda, use of formal language, and use of graphs and plots. There were also statements which resulted in emergency management professionals disagreeing with the student groups: the 'why' of the crisis, discussing past crisis scenarios (i.e., context), and the communication of probabilities.

To investigate any relationships between the communication proxies, we compared the scores of the communication experience (CE), confidence (SPCC), and perceptions (PCC) to one another. Though there were no statistically significant associations between pre- or post-scores within the instruments, but we did find a positive relationship between the changes achieved in confidence and perceptions, indicating that students who experience positive shifts in confidence, also experienced positive shifts in perceptions. This means that for some participants, the SBRP was duly effective in both dimensions resulting in an overall, challenging but highly beneficial learning experience.

Lessons learned from this project include: 1) the buy-in from instructors of courses is crucial for a successful integration in the curricula; 2) the amount of flexibility in the design of the SBRP is not as large as we thought it would be; and 3) the value of having a full-time postdoctoral fellow working on the project, rather than multiple part-time employees. In the near future, we plan to collaborate with various stakeholders to bring the SBRP to professional development opportunities for practicing emergency managers in New Zealand.

Future research will include a more detailed characterisation of the phase two pre and post qualitative data to more clearly link the communication proxies to the experiences in the SBRP and attempt to make causal inferences of the proxies to the communication performance of participants.

1. Introduction

Communicating scientific results, conclusions, and recommendations about natural hazards and disasters into language easily understandable by various non-expert stakeholders can be a challenging task at the best of times. However, during a (threat of) crisis, when an actual natural disaster is looming or unfolding, communication becomes even more difficult. Different information needs of stakeholders, compressed time frames, high expectations about the quality and quantity of science communication, and high degrees of uncertainty in the scientific data, make science communication particularly challenging in these situations. Professional scientists are typically not formally trained in communication, while communication and media experts on the other hand are generally not trained in science. As a result, science communication can be suboptimal in times where clear and effective communication is the most important. Several instances in the recent past serve as telling examples.

The Canterbury Earthquakes Royal Commission noted failings in incident command due to poor communication and recommended that the Ministry of Business, Innovation and Employment and GNS Science improve the communication of earthquake and building risks (Canterbury Earthquakes Royal Commission, 2012). In addition, the geoscience community struggled to counter the pseudoscience of the popular “Moon Man” Ken Ring (Bayer, 2011). Lastly, the initial manslaughter convictions of six seismologists and a public official in the aftermath of the L’Aquila earthquake in Italy (overturned in November 2015 for the six scientists, upheld for the public official) led to many scientists being more cautious about science communication. All this underscores a strong need for, and importance of effective science communication preparation for students and professionals in the field (Jordan et al., 2011) to meet the demands of a scientist’s professional life.

The examples listed above have served as an impetus for the professional field of hazards and disaster management in New Zealand and abroad to review their procedures and training. This project jumped into that window of opportunity for change. We aimed to develop and evaluate a training exercise, not only for learners in formal education, but also for working professionals in natural hazards and emergency management. We’ve developed a scenario-based role-play (hereafter *SBRP*) involving an earthquake scenario on the West Coast of New Zealand called: ‘***Communicate the Quake’***.

In this report, we discuss the evaluation of the SBRP and its impact on our students’ communication skills. The project aimed to contribute to the practical knowledge of the teaching and learning of science communication skills, conveying, receiving, and interpreting (verbal and non-verbal) information to and from educationally, culturally, and politically diverse stakeholder audiences.

The main goals of the project include:

1. The research and development of an authentic and realistic science communication SBRP, grounded in best practices and the scholarly literature
2. The evaluation of the SBRP using selected student groups; and
3. The analysis of students’ communication experience, confidence and perceptions before and after the use of the curriculum.

Our project was built upon literature in role-play and simulation (e.g., Errington, 1997; van Ments, 1999) and the in-house teaching and learning expertise at Canterbury in geoscience education (e.g., Kennedy et al., 2013), as well as natural hazard education, in particular several years of experience in design research culminating in a SBRP called the Volcanic Hazards Simulation (Dohaney et al., 2015).

We hope this project will contribute to the literature on role-play and simulation, communication training, as well as design-based research (e.g., Barab and Squire, 2004). In addition, it provides a very practical suite of teaching tools, design and evaluation methods for (geo)science education for other organisations to use as "off-the-shelf" products. The SBRP, depending on configuration, takes several hours to run, and is thus suited for both traditional formal education, and continuing professional development formats, the latter of which is typically done in intensive block format curricula.

2. Rationale for a Scenario-Based Role-Play design about earthquakes

2.1 Why Scenario-Based Role-Plays?

We define a scenario-based role-play (SBRP) as an intensive and immersive, experiential learning exercise, utilising a complex realistic scenario as a core narrative which guides the learning. A SBRP is one of the many examples of authentic learning which focuses on real-world, complex problems and their solutions taught within authentic environments through activity and social interaction (Herrington & Herrington, 2006; Herrington, Reeves, & Oliver, 2014; Lombardi, 2007).

The effectiveness of role-play and simulation for learning has been reported in a number of studies (e.g., DeNeve & Heppner, 1997; van Ments, 1999). In role-play, participants take on an authentic role in a pre-defined, realistic scenario, and act and interact with others in the capacity of that role (Erringon, 1997; 2011). SBRPs support students and professionals to practice their skills in a safe and controlled situation. For students, SBRPs provide an opportunity to experience what it is like to be a working professional in the field; an experience that cannot easily be obtained through other teaching formats. SBRPs have been used successfully in a variety of fields, such as environmental sciences, law, medical sciences, and the military. In addition, they are also quite common in the hazards and disaster management professional sector (a.k.a., training exercises), meaning that an SBRP experience provides students professional development for the workplace.

In several research studies, role-plays and simulation have been shown to improve student attitudes towards learning (DeNeve & Heppner, 1997; Shearer & Davidhizar, 2003; van Ments, 1999); interpersonal interactions (Blake, 1987; Shearer & Davidhizar, 2003; van Ments, 1999); generic transferable skills (problem-solving and decision-making skills, Barclay, Renshaw, Taylor & Reyan Bilge, 2011; Errington, 1997); communication skills (e.g. Hales & Cashman, 2008; van Ments, 1999); teamwork skills (Harpp & Sweeney, 2002; Maddrell, 1994), as well as discipline-specific knowledge (DeNeve & Heppner, 1997; Livingstone, 1999). With such positive learning benefits, we felt that SBRPs are widely beneficial and also specifically support our project goals to improve students' communication.

2.2 The Volcanic Hazards Simulation

In her doctoral thesis, Dohaney (2013) investigated, among other things, the pedagogical design of a SBRP about a volcanic eruption; the Volcanic Hazards Simulation. In this exercise, students take on roles as scientists from GNS Science (Geological and Nuclear Sciences) and emergency managers monitoring and managing a national-scale volcanic crisis, in two different scenarios (Tongariro National Park or the Auckland Volcanic Field). Over the last five years, it has been successfully used at the University of Canterbury, the University of Auckland, and Simon Fraser University (Canada), to teach 300- and 400-level geology, hazards management, and environmental science students about data interpretation, interdisciplinary teamwork, emergency management, and science communication skills.

A strength in the design of this SBRP was that, regardless of the students decisions (e.g., evacuations and the raising or lowering of Volcanic Alert Levels (Geonet, 2011), the whole group (20-40 students) must work collectively towards mitigating the 'disaster'. The students spend a considerable proportion of time working through these decisions during the simulation. The focus of the activity is not necessarily about making the 'right' decisions, but through iterative mistake-making and successes the students learn about the difficult decisions that scientists and emergency managers face during these important events. Through communication of scientific uncertainties, unknowns, and sensitive topics (e.g., volcanic impacts to one's community, or business) students experience the diverse challenges of volcanic hazards.

2.3 Why Earthquakes?

'Communicate the Quake' focuses on responding to an earthquake event. This was done for several reasons. First, the events in Canterbury in the last years have generated considerable interest from natural hazards and emergency management professionals in science communication. This meant that a scenario focused on the communication of earthquakes was likely to attract buy-in from the professional sectors. Second, many of the research team members had experience with (but not necessarily involvement in) the science communication efforts during the Canterbury Earthquake Sequence, and thus were able to draw on "lessons learned" from those events. Third, minor and major earthquakes occur frequently in New Zealand and communication around these events will be needed on a regular basis. In particular, seismicity associated with, or in close proximity to the Alpine Fault, will require careful communication. The Alpine Fault is one of the most significant seismic hazard in New Zealand, capable of generating a magnitude 8 earthquake. Robinson and Davies (2013) estimated that the probability of the Alpine Fault rupturing within the next 100 years is 85%.

Another reason to choose an earthquake-related scenario was its suitability for modular extensions in the future. Earthquakes affect a broad range of stakeholders requiring consultation from numerous professional areas (e.g., structural engineering, economics, and disaster recovery). This makes the SBRP a versatile and extendible platform for use in other areas beyond those targeted directly in this project.

2.4 Why Communication?

Unlike the Volcanic Hazards Simulation, 'Communicate the Quake' focuses primarily on science advice and science communication, rather than the scientific decision-making and prediction per se. Our primary motive, as can be inferred from the introduction, was to develop tools to help students and professionals in the field of geology, engineering, and hazard management prepare for their role as *communicators of science*. Communicating science to different stakeholder audiences is not typically part of the academic preparation of scientists and engineers.

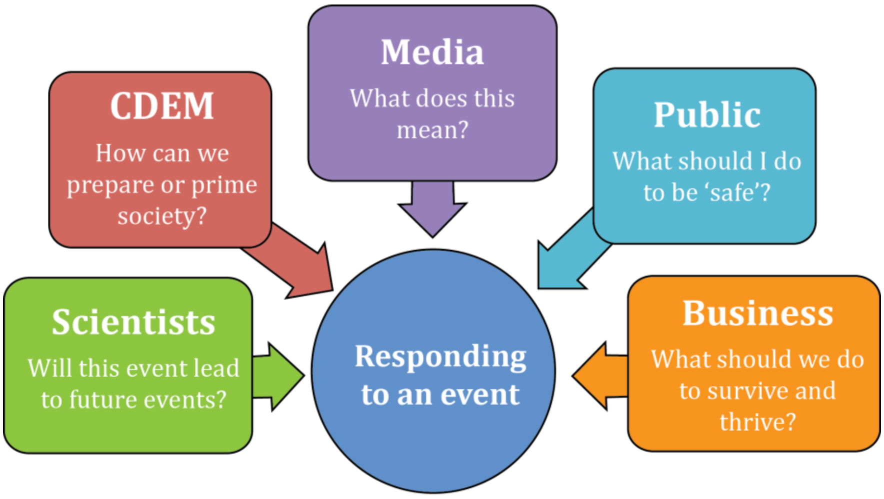


Figure 1: Examples of stakeholder's information needs during a crisis

In the event of a crisis, scientists may well be called upon by media or other stakeholders to share their knowledge and expertise, and need to be cognisant of the different information needs of these different stakeholders. An example of some potential stakeholders' queries (information needs) in response to an event is shown in Figure 1. Unfortunately, those types of communication are also the most difficult, given the typical high-stress and high levels of (scientific) uncertainty in unfolding earthquake events, and the fact that the communication is not just about the earthquake itself, but also about the (anticipated) public reaction to the earthquake. In particular, science misconceptions (e.g., due to differing mental models; Morgan, Fischhoff and Bostrom 2002) and mistrust of science communicators (Haynes, Barclay and Pidgeon, 2007) can both impede effective science communication.

In addition, it is fair to say that communication is a valuable 'transferrable skill' in and out of the classroom, and it is sought out by employers in all fields (e.g. Hambur, Rowe, & Tu Luc, 2002; Careers NZ, 2013). Various disciplines (e.g., nursing, engineering and law) have recognised the need for incorporating communication in the curriculum (e.g.; Paretti, 2006; Paretti, 2008, Norgaard et al., 2012). However, teaching people about communication is different from people actually doing communication. For people to become more proficient in communicating, authentic practice needs to occur for the skills to be honed. We wanted to give participants in the SBRP a variety of experiences aimed to improve communication competence and confidence in four areas:

- Communication with different stakeholder audiences and their associated information needs. This includes the notion that communication is not a linear

"transmission" model (Fischhoff, 1995; Fisher, 1991), but rather a dialogue and partnership with the target audience as supported by the Sendai Framework for Disaster Risk Reduction (USINDR, 2015).
- Communication of scientific uncertainties with a spectrum of data ambiguities (many possible outcomes).
- Communication using different media, and judging which media are appropriate for which type of communication
- Communication delivery using current best practices

Scenario-based role-plays are effective in oral communication because of the noticeable impact of the messenger's non-verbal communication (McCabe & Timmins, 2003), rather than just the content of the message. This requires students to think about the situational needs and agendas of each stakeholder (Livingstone, 1999), and adapting and reflecting upon their approach when conflict and negative relationships occur (e.g., Shearer & Davidhizar, 2003).

Acknowledging that there is a vast literature on hazards and disaster communication (a discussion of which is beyond the scope of this report), we opted to use communication best practices based on the "7Cs" taken from Bryner (2012), who was influenced by the works such as Miller (2008) and Weingart, Engels, & Pansegrau (2000). The 7Cs say that science communication should:

- be **comprehensible** (i.e., is simple, jargon-free, clear and concise)
- be **contextualised** (i.e., acknowledges and reflects diversity of your audience)
- be **captivating** (i.e., is entertaining, engaging, salient, and relevant to everyday life)
- be **credible** (i.e., is open, does not overpromise, acknowledges uncertainty)
- be **consistent** (i.e., is backed by evidence, confirmable, coordinated and collaborated sources of information)
- be **courteous** (i.e., is compassionate, empathetic and respectful)
- address **concerns** (i.e., empowers action and response, forms a dialogue)

3. Basics of 'Communicate the Quake'

3.1 Classroom Context and Learning Goals

'Communicate the Quake' was developed in the first instance for late undergraduate to early postgraduate target audiences in geology, hazards and disaster management, and earthquake engineering. The SBRP is included within a module that can be run over 1-3 weeks, depending on the level of the students, their prior knowledge, and the learning outcomes for the course. The module comes with two components: Preparation materials (pre-activity lectures, readings, supplementary homework assignments), and the exercise itself. The preparation materials are meant to familiarise students with basic concepts as well as the geographic area in which the scenario is set.

Prior to 'Communicate the Quake', students should be familiar with:

1. The variety of hazards and scale of damage caused by earthquakes.
2. Reading and understanding geological and topographical maps.
3. How, why, and where earthquakes occur.
4. A general idea of what scientists and emergency management professionals do during a crisis.

In the "general theme" mode, the SBRP preparation consists of three lectures (earthquake science I, II, and best practices in science communication, 90 minutes each) followed by two exercises (earthquake hazard mapping activity (2-4 hours), critique of a media release and media interview (1-2 hours)).

The SBRP itself is then run a week later, allowing for students to be assigned to roles and do pre-activity readings to familiarise themselves with their roles. It can be run with small (8-10 students) and medium-sized (30-40 students) student groups. Roles (see below) can be shared or omitted, depending on class size. It requires a minimum of 2-3 facilitators who are familiar with the materials. The SBRP is assessed using peer- and self-evaluation rubrics, but can be assessed in different ways as well, depending on instructor preference. We recommend that all pre-activities be assessed as part of the course to encourage engagement and accountability.

Based on the diversity of students' academic backgrounds and the course goals, the learning goals for the SBRP can differ. However, the SBRP itself has core learning goals which all versions must maintain.

After 'Communicate the Quake', students should be able to:

1. **Summarise** and **communicate** (in plain speak) the characteristics (magnitude, depth, frequency, energy release) of a given earthquake event;
2. **Compose** and **deliver** multiple formats of communications: town-hall/community meetings, media releases and bulletins, web-based communications, headlines for media, press conferences;
3. **Communicate** the scientific uncertainties associated with an ongoing earthquake event. (For example, answers to question like: "what happens next?"; "when will the next earthquake occur?"; "how certain are you that this event will not get 'bigger'?");

4. **Describe** and **communicate** impacts to infrastructure and society from a large earthquake near Greymouth NZ.;
5. **Communicate** effectively in all scenarios. Criteria for effectiveness includes information which is organised, accurate, relevant, readily understood (including the message and the use of jargon), and delivery which is competent (i.e., appears approachable and comfortable with communicating) and culturally inclusive;
6. **Estimate** and **illustrate** impacts from an earthquake event based on the earthquake characteristics in order to create maps to effectively communicate with impacts public;
7. **Have an awareness** of scientists and emergency manager's responsibilities, agendas, and expertise; Team structures, hierarchy and protocols; and
8. **Have an awareness** of audience information needs. **Prioritise** pieces of information to specific situations and audiences. **Communicate** earthquake event information specific to multiple stakeholders (i.e., homeowners, industry sectors, affected communities, scientific community).

Note that in this project, we did not explicitly set out to measure the learning goals, but to create an environment in which those learning goals could be achived. Our aim in the first phase of the study (see section 4) was to ensure that there were no roadblocks in the design so that students were given optimal opportunity to meet the learning goals. Learning goals 5 and 8 were the main focus of the second phase of the study.

3.2 The Scenario, Roles, Teams, and Communication Tasks

'Communicate the Quake' is set in Greymouth, on the west coast of the South Island of New Zealand. The scenario begins prior to any major earthquake events (i.e., 'business-as-usual'). We fast-forward to several months later when a large earthquake occurs on the Hope Fault (e.g.. Van Dissen and Yeats, 1991), with an epicentre which is approximately 40 kilometers away from Greymouth. The earthquake causes local and regional damage and the scientists and emergency managers must respond to provide advice to the public. Several months later (fast-forward, again), a second and larger earthquake event occurs which causes more damage to the area. The public becomes concerned that these Hope Fault earthquakes may trigger a larger, and devastating Alpine Fault earthquake. Throughout the scenario, scientists and emergency managers must work together to respond appropriately to address stakeholders' concerns.

Students are assigned to either of two teams: civil defence and emergency management (CDEM) or the science advisory group (SAG). CDEM consists of 8 roles, which include: Group Controller (team leader), Duty Manager, Infrastructure Coordinator, Planning Manager, Welfare Officer, Human and Society Impacts Specialist, Economic Impacts Specialist, and a Public Information Officer. The CDEM team is tasked with coordinating and managing the impacts from a disaster event. The SAG also consists of 8 roles, which include: Chief Science Advisor (team leader), Duty Manager, GNS Seismologist, GNS Field Geologist, Earthquake Engineer, Landslide Specialist, Liquefaction Specialist, and a Public Information Officer. This SAG team must provide scientific information to the CDEM team, and to the public.

The roles and responsibilities used within the SBRP are modelled after the New Zealand emergency management organisational structures (Ministry of Civil Defence &

Emergency Management, 2013). However, roles and team structures are simplified to allow for less complex inter- and intra-team communication. Together, the groups are responsible for a number of communication events that appear in the scenario. Participants engage in the following (oral and written) communication tasks:

Part 1 (1-1.5 hours) is concerned with earthquake preparedness of Greymouth prior to the earthquake event. It is in a **Town Hall Meeting** format with an **information pamphlet** and is a successful ice-breaker and introduction to the role-play (if students are unfamiliar or shy).

Part 2 (1.5-2 hours) occurs immediately after a large quake, which causes local and regional damage. This Part is focused on information needs and first response. It includes a **Media Release**, a **Radio Bulletin,** and concludes with a **Press Conference**. It should be fast-paced, and can be improvised/guided as needed.

Part 3 (50-60 minutes) is a **Panel Discussion** (built around social media injects from the public), where experts are called upon to discuss the uncertainty of earthquakes, and address the public's concerns. This section addresses the common misconceptions held by the public, in earthquake science and science in general.

Part 4 (10-20 minutes) is a post-exercise **Debrief**. Students are asked to think about what happened that day, and how they feel it went. Instructors may choose to run this as a discussion, or as a written assignment. It is designed (by default) as a written assignment. This can be used on the day, or in the days/weeks following as a homework exercise.

As the scenario unfolds, instructors provided support, feedback and challenge the participants.

3.3 Under the Bonnet: the Tools of the Exercise

Students have access to a wide variety of tools to work within the scenario. The SBRP relies on computers and internet access to run. The scenario itself is in PowerPoint, as it is ubiquitous and easily transferrable. The communication tasks are team efforts, and as such file-sharing and collaborative development platforms (e.g. Google Docs) are used to share information (in real-time). In addition, students are provided with Google Earth layers before and during the SBRP which illustrate the infrastructure and geology of Greymouth and the effects of the earthquake events (see Figure 2). These layers were custom-designed to suit the Greymouth scenario.

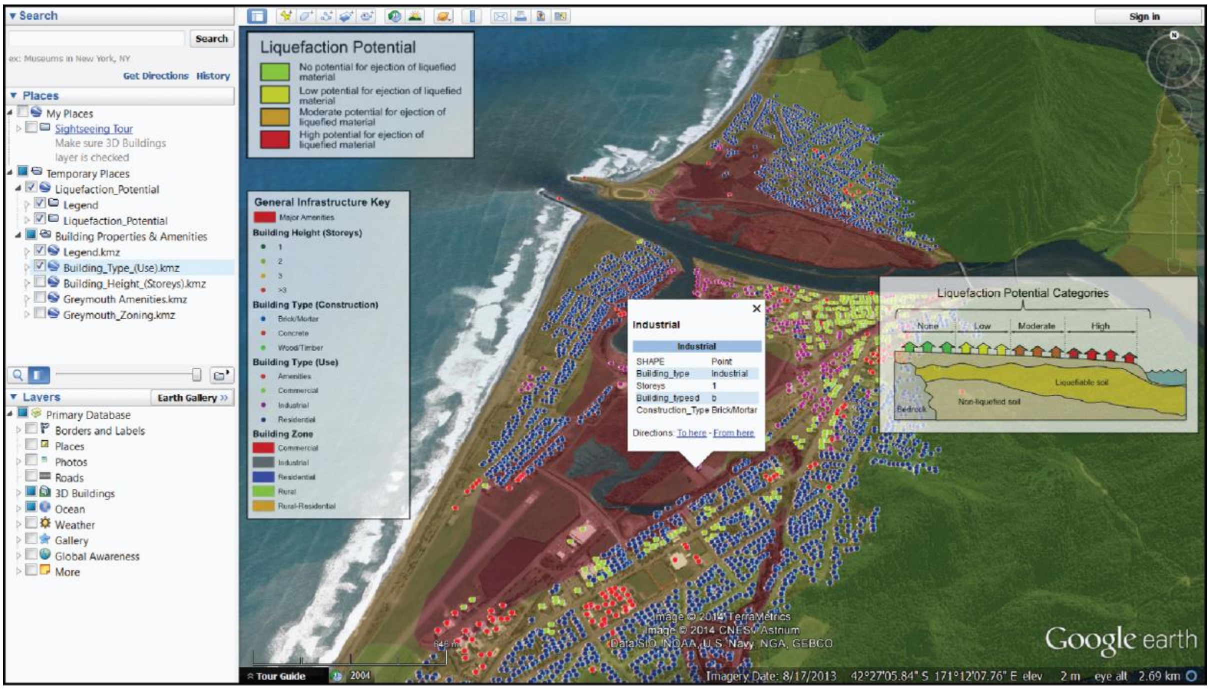


Figure 2: Customised Google Earth layers for the Greymouth region

A detailed instructor manual has been developed for 'Communicate the Quake'. It contains instructions, suggestions, logistical and pedagogical considerations. This user manual is available at http://serc.carleton.edu/introgeo/roleplaying/examples/143264.html

4. Research Design and Methodology

4.1 Iterative Design Approach

We used an iterative design approach in this study that consisted of two distinct phases. Phase one (i.e., Design Phase) constituted the development of the SBRP, and data collection to measure its performance for further development purposes. Phase two (i.e., Communication Research Phase) constituted data collection to measure students' communication performance. Table 1 shows the various iterations of the SBRP. The pilot and iterations 1-3 were part of phase one, while iterations 4-6 were part of phase two (shaded in Table 1). In the remainder of this document, we will refer to the pilot as "it0" (iteration 0), and abbreviate the other iterations as "it1" through "it6".

Table 1: Description of iterations 0-6

Group	Place	Date	N	Instructors	Description
Pilot (Iteration 0): General Earthquake Science **(GEN)**	UC, Emergency Operations Centre (EOC)	Feb 17 2014	13	3	Two teams, SAG and CDEM, some roles have changed in later versions. Detailed preparation activities were included to introduce basic concepts to these students. Pre activities and SBRP were assessed using rubrics.
Iteration 1: Active Tectonics **(TECT)**	UC, EOC	April 10 2014	14	2	One team; SAG-focused. No pre-activities, aside from role and responsibility readings. Not assessed.
Iteration 2: Hazards and Emergency Management **(HAZM)**	UC, Hari hari Field station	April 24 2014	16	5	Two teams, with emphasis on emergency management (CDEM) topics. Some repeated participants from it1. No preparation activities, aside from student readings. SBRP assessed through a rubric.
Iteration 3: Engineering Research Group **(ENG)**	UC, EOC	May 27 2014	7	1	One team; Eng-focused. Small group. No preparation or pre-readings were done. Students broken up into 'interest groups' (liquefaction, rock fall and geo-engineering) rather than distinct roles. Not assessed.
Iteration 4: General Earthquake Science **(GEN)**	UC, EOC	Feb 8 2015	15	4	Two teams, SAG and CDEM; Detailed preparation including science communication lecture and homework. Pre-activities and SBRP were both assessed using rubrics.
Iteration 5: Emergency Management Summer Institute **(HAZM-PRO)**	Massey U, classroom	March 2 2015	19	5	One, very large team. CDEM-focused. Small SAG-group within the team. Participants were contacted prior to exercise, but few were able to respond and do pre-readings. Difficulty with instructors and participants adhering to the tasks as 'authenticity' became a barrier to learning. See section 5.5.
Iteration 6: Hazards and Emergency Management **(HAZM)**	UC, EOC	July 21 2015	10	3	One team; CDEM-focused. Included two SAG advisors included within group. Students were asked to do pre-readings, but many admitted to not 'getting around to it'. Not assessed.

We used this iterative design approach for two reasons. First, the SBRP is inherently complex, with various variables almost certainly interacting. Making too many changes at any one time thus would complicate our ability to make causal inferences about the effectiveness of any one change. Second, the SBRP was tested in several cases in real classroom environments. This meant that we had to ensure that in any iteration the SBRP would work adequately as a teaching and learning tool to achieve the learning outcomes for the class. Making many changes at once increases the risk of the SBRP not being able to fulfil this function.

Incremental development and refinements were based on observations and (pre- and/or) post-event semi-structured interviews with participants to assess their attitudes, and behaviour in the SBRP. In the first phase of the study, the task structures, participant cognitive load, presentation and format of the data streams, and the general "look-and-feel" and authenticity of the SBRP received close attention. In this phase, we drew heavily on our experiences in designing and evaluating the Volcanic Hazard Simulation (Dohaney et al., 2015). The SBRP is an inherently complex system, meaning that it is not possible to change individual variables without affecting others. For example, creating an environment in which students can learn to communicate requires constructive and timely feedback. This means that time has to be set aside for this to occur, which influences the (complexity) of task structures and participant cognitive load. In the second phase the focus shifted to communication performance, which was the main objective of this study. All iterations attempted to achieve the learning goals in section 3.1.

4.2 Participants and Data Collection Procedures

In total, data from 94 participants were collected (both students and emergency management professionals). In addition, we collected data from 23 instructors (see Table 1). Most were third and fourth year students in geology, hazard management, earthquake engineering, emergency management and related fields at the Universities of Canterbury, Auckland, and Massey. These students were recruited from the courses that the team members currently teach. A second group of participants was part of the Frontiers Abroad exchange programme (a geology field based programme), and consisted of students from the United States. The last group of participants were professional emergency managers (iteration 5). More detailed demographics from participants in Phase 2 of the study can be found in Table 2 (note that Phase 1 focused on the SBRP itself, rather than participants' changes; hence, we have omitted Phase 1 from Table 2)

The data collection for the different iterations of the SBRP is summarised in Table 3. We collected classroom observations and questionnaires, which included debriefs and communication surveys. Focus group interviews were also carried out with one set of instructors. In the section below, we discuss the instruments in more detail.

Table 2: Phase 2 Participant Demographics

Iteration	age (n)	Gender (n)	Nationality (n)	Degree programme (n)
4 **(Frontiers Abroad exchange students)** (15 participants) Jan 2012	19-22 (14) ≥ 23 (1)	female (9) male (6)	United States (14) Other (1)	Engineering (2) Earth/Environmental science (11) Other (2)
5 **(Hazard management Professionals)** (10 participants) Aug 2012	19-22 (0) ≥ 23 (10)	female (4) male (6)	New Zealand (7) Other (3)	N/A
6 **(UC Students)** (10 participants)	19-22 (6) ≥ 23 (4)	female (13) male (30)	New Zealand (9) Other (1)	Professional Masters, Hazard and Disaster Management (7) MSc, Geology (1) PGDip, Geology (1) Other (1)

Table 3: Data Collection

Phase	Group	Observations	Student Debriefs	Instructor Debriefs	Communication Experience	Self-Perceived Communication Competence	Perceptions of Crisis Communication	Quizzes	Pre-post Interviews
Phase 1: Design	**Pilot (it0)**: General	Y	Y (12)	Y (2)					
	it1: Tectonics	Y	Y (10)	Y (0)					
	it2: Hazards	Y	Y (2)	Y (0)					
	it3: Engineering	Y	Y (6)	Y (0)					
Phase 2: Communication	**it4**: General	Y	N	Y (4)	Y (15)	Y (15)	Y (15)	Y (15)	Y (8 sets)
	it5: Hazards (Pros)	Y	N	Y (5)	Y (8)	Y (8)	Y (8)	Y (5)	Y (8 posts)
	it6: Hazards (Students)	Y	N	Y (1)	Y (11)	Y (11)	Y (11)	Y (9)	Y (6 sets)
	Total n	**7**	**30**	**12**	**34**	**34**	**34**	**29**	**14 sets, and 8 posts**

4.3 Instruments and Data Analysis Procedures

Figure 3 shows schematically how we view communication performance. Experience, perceived competence (i.e., confidence), content knowledge, and the perceptions of communication all factor in how well a person is able to communicate. To assess communication performance, it is thus important to measure the factors contributing to this performance. We used a mix of existing instruments and instruments that we developed and validated as part of this study. Table 4 provides an overview of the instruments used. In the subsections below, we briefly expand on each of the instruments.

In phase 2 of the study (iterations 4, 5, 6) students were surveyed before and after the exercise. Participants in iterations 5 did not respond to the pre-exercise survey email, so only post-exercise responses were collected. Surveys were handed out both in hardcopy and electronically, and reminder emails were sent to try and improve response rates. Iteration 4 was surveyed the evening prior the exercise, while iteration 6 was surveyed up to a week prior (due to logistics rather than research design). All iterations were also surveyed immediately after the exercise.

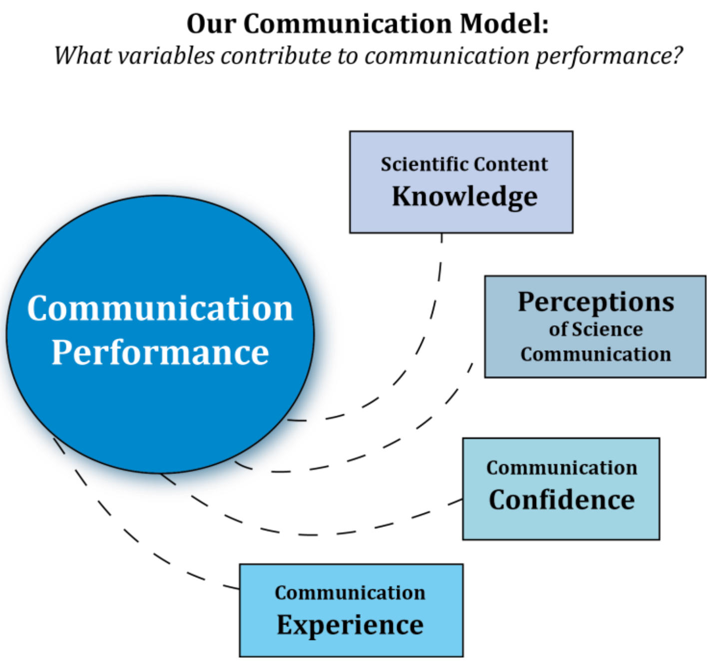


Figure 3: Our model of communication performance

Table 4: Communication Instruments

Proxy	Instrument	Comments
Communication **experience**	Communication Experience Questionnaire (**CE**; Appendix 2)	Developed and validated as part of the project. Administered pre-SBRP
Communication **confidence**	Self-perceived communication competence scale (**SPCC**)	Existing validated instrument (SPCC, McCroskey and McCroskey 1988) Administered pre- and post-SBRP
Perceptions of crisis communication	Perceptions of Crisis Communication Questionnaire (**PCC**; Appendix 3)	Developed and validated as part of this project. Administered pre- and post-SBRP
Earthquake content **knowledge**	Quizzes (Appendix 6)	Tailored to the learning goals of the target group. Not validated measure Administered pre- and post-SBRP
Actual communication ***Performance***	Interviews (Appendix 7) In-class video observations	Qualitative assessment supported by the literature Interviews administered pre-and post-SBRP

4.3.1 Classroom Observations

We collected approximately 30 hours of observation footage. Data collection was overt (Jorgensen, 1989). Observers were introduced to the students and their purpose for being present was explained. Almost all iterations were done in a multi-room setting and required multiple observers. Observation summary notes were taken in all iterations, with increments of approximately 2 minute "checks".

Classroom observations in phase 1 of the study concentrated on the core design element of the earthquake SBRP. The main goal was to infer whether the SBRP was meeting its intended learning objectives. To this end, we focused on determining which curricular elements were either promoting or inhibiting student learning (e.g. whether a task was too difficult or unclear), and to create a timeline of events of student behaviours (e.g. did the SBRP keep students engaged, level of interaction between facilitators and students, group dynamic conflicts, pace of the tasks, successes and failures on tasks, evidence of breaking flow, etc). The observations were holistic in nature, rather than tracking all participants and facilitators individually.

Observation footage complemented the notes, and neither was not specifically coded. Rather, notes and footage served as an tool to help us inform what participants were doing when during a series of complex tasks, and determine whether that was in line with what we intended. The aim was to inform pedagogical and curricular changes in the design. The purpose of the footage and observations was to help identify broader and holistic themes, focused on behaviours that signaled design successes or failures (e.g., off-task behaviour of one student (not necessarily a design failure) versus off-task or conflict behaviour in a group (quite possibly a design failure)).

Observations in the second phase of the study focused on team dynamics and communication, though we also checked, like in phase 1, whether the design of the SBRP continued to be adequate for the tasks. In particular, we noted successes and failures in communication and what pedagogical factors were influencing that. We also used the data to ascertain which students were participating in which tasks. In future research, we will be comparing video footage of communication tasks within the SBRP to pre- and post-interview data of specific students. This, however, is beyond the scope of this report.

4.3.2 Student and Instructor Debriefs

In the first phase of the study, two debrief questionnaires were used after the exercise to collect feedback from participants and instructors about the successes and failures of the exercise. In the second phase, we continued to collect this data from the instructors, but not the participants (as we were already collecting communication data from them). The debrief questions and their results can be found in Appendix 1.

Responses to open ended questions were transcribed and coded using ATLAS.ti qualitative software (Friese & Ringmayr, 2011). We used content analysis, which is the process of using systematic and verifiable means of summarising qualitative data (Cohen, Manion, & Morrison, 2007). Responses were grouped by the pre-determined questions, items were recorded verbatim, summarised when repeated items occurred, and categorised together into broad themes.

4.3.3 Communication Experience

Participants were given a survey on the amount and types of communication experiences they have had. The experience survey can be found in Appendix 2. Here, we only discuss section A of the instrument (sections B and C were used for validation and instrument internal consistency purposes. This will be explained in more detail in an upcoming scholarly paper on the design, development and validation of the instrument). As it would be impossible for a participant to remember the number of experiences precisely in each of the 14 categories in section A of the instrument, we made relatively broad bins: No experience, Few experiences, some experiences, many experiences, and numerous experiences. For each of these statements, the bin size varies. This came out of our validation process and the distinction is based on the fact that certain communication experiences will be more common than others, allowing for relatively easy discrimination between the bins. To calculate the total Communication Experience (CE) score, we assigned numerical values 0-4 to the (ordinal) bins and simply added the scores. This gives a maximum CE score of 56 (14 times “numerous experiences” which has a value of 4). This approach means that no sophisticated statistical analysis can be performed, as the sum of ordinal data has no mathematical meaning beyond a qualitative order of magnitude estimate. We do use means in the descriptive analysis, but these should be treated with caution and only used as a first-order approximation. A similar caution is warranted for our (non-parametric) tests on the data. The Communication Experience instrument will be discussed in more detail in Dohaney et al. (forthcoming).

4.3.4 Perceptions of Crisis Communication

The perceptions of crisis communication survey was developed as part of this project, following a similar strategy to Adams et al (2006, and references therein) and their suggested treatment of data. The instrument uses a baseline of experts to provide answers to the questions, to which other participants are then compared. Similar style instruments were used by Kennedy et al. (2013) and Jolley et al. (2012). The survey itself can be found in Appendix 3. In total, 44 experts in the field of geology, engineering, emergency management and science communication provided answers to establish the baseline. Note that while we asked experts for their view on communication with different stakeholder audiences, here we focus on scientists communicating science with the public, as that is the main focus of the SBRP. The CE instrument was trying to capture a range of communication experience, both current (education and workplace) and past.

Experts were sourced from universities (26), Crown Research Institutes (12), other government agencies (3) and other (2). They consisted of geologists (21), engineers (2) Emergency Managers (1), social science researchers (20), including Disaster Risk Reduction specialists (7) and communication researchers (9). Experts came from a range of career stages and had on average 17 years of experience. Twenty-five were female, and 19 were male, and not all had science communication as an explicit part of their job description (26 no versus 18 yes). Experts were asked to rate their experience with levels of oral communication on a scale of 1-10 (TV and radio interviews, press conferences, town-hall meetings. Respondents ranged across the entire spectrum, with a mean of 5.5. We split the data into two groups: 5 or less (23), versus more than 5 (19, note that two people did not answer). In addition, virtually all experts had communicated science at some point in professional venues (e.g. conferences or other venues in which the target audience are fellow scientists) rather than with the general public (37 out of 44).

The 5-point scale in the instrument was then collapsed to "disagree, neutral, agree" to smooth out the distinctions between strongly (dis)agree and (dis)agree. The expert response results are listed in Appendix 4. For the vast majority of the statements, there was a strong consensus answer among the experts. The criteria of non-consensus were: median or mode of 3, and/or a strong neutral component and/or a bimodal agree/disagree in the distribution. In those cases where there was no clear consensus, we examined the data by subpopulation (geologists, engineers, emergency managers, science communicators) and demographic variables to try and account for the lack of consensus. The statements that showed lack of consensus were: 2, ***3***, 8, 14, 20, 25, ***26***, ***33***, 35, ***42***, 45 and 49 (bolded and italicised number are statistically significant for one or more demographic variables). We refer to Dohaney et al. (2015b), which discusses the development of the instrument in more detail, as this is beyond the scope of this report. In terms of comparing student data to expert data, if no consensus is clear in the expert data, the best we can do is to examine whether the student distribution is similar to the expert distribution. The Perception of Crisis Communication instrument will be discussed in more detail in Dohaney et al. (forthcoming).

4.3.5 Self-perceived Communication Competence Scale

We measured communication confidence through the validated Self-Perceived Communication Competence (SPCC) instrument (McCroskey & McCroskey, 1988, and references cited therein). The SPCC consists of 12 items on which participants self-report (on a scale of 0-100) their ability to communicate in different contexts (public, meeting, group, one-on-one) and different target audiences (strangers, acquaintances, friends). We used a 10-point, rather than a 100-point scale (primarily to reduce data noise), ranging from 0 (poor ability to communicate / incompetent) to 10 (strong ability to communicate / very competent), but made no further changes to the instrument. For details on this instrument, please refer to McCroskey and McCroskey (1988).

5. Phase 1: Design Research - Results and Discussion of the SBRP Design

In this section, we present and discuss the results of the design phase of the study. We start with a brief discussion on the communication tasks which were used in the SBRP and how some tasks were removed, as they did not work. Appendices 1B-D illustrate the instructor and student debrief results that were held after most SBRP iterations (see Table 4 for details). Several major themes emerged from this data: 1) Preparation (Section 5.2); 2) Technology (Section 5.3); 3) Team dynamics (Section 5.4); and 4) Authenticity (Section 5.5).

5.1 Communication Tasks

The 'Communicate the Quake' SBRP consists of four parts, which include communication tasks (i.e., different formats of communication, see section 3.2). The early versions of the SBRP included numerous formats: Town-hall meetings, media releases, radio bulletins, press conferences, infographics, one-on-one media interviews, structured group discussions, panel discussions, and a reflective debrief. Based on feedback from students and instructors, tasks that did not perform as expected (i.e., were unsuccessful and did not support the learning goals) were removed. The 'final' version is described in section 3.2 and more detailed information can be found in the instructor manual (Dohaney et al., in prep).

The infographics task was removed because we found we had overestimated students' abilities with graphics and word processing software packages. Students would have needed much more time to design maps in 'real-time' than was practically feasible in the exercise.

The one-on-one interviews were removed because it did not allow for more than 2 students to participate at a time. We leaned more towards communication tasks which involved all the students, rather than few, to maximise the amount of practice that each student could have by the end of the SBRP.

5.2 Preparation

In the debriefs, students and instructors alike reported that students were not familiar enough with their roles. Background information on all roles was provided because the roles students adopt in reality would require a considerable amount of experience and specialist knowledge. As the purpose of the SBRP is to practice communication, distractions about what the role entails need to be minimised. However, students self-reported not always reading the background materials that were provided. In many instances students reported wanting resources to prepare for their role, not realising that these materials were actually already available to them. This means that it is crucial for instructors to both provide the background materials well in advance and to strongly emphasise the need to prepare for the exercise. One good way to ensure preparation is to make it part of the assessment of the exercise (Dohaney et al., 2015).

Despite some lack of preparation on the students' part, the exercise was considered a fun and worthwhile learning experience from the students' perspective. A typical student quote illustrates this: "It was a really fun simulation to do. I thoroughly enjoyed the learning experience. The tasks were well thought out and all roles were accounted for. I enjoyed taking on the role of Duty Manager and I learnt a lot as I had never experienced being in this role before. I think it was a great task for us all to do and I wish we had more learning experiences like these." (it1).

5.3 Technology

Observations and debriefs revealed that SBRP participants had varying levels of success working with the technology used in the exercise (Google Earth, file sharing, Google Docs). In some cases, this was a severe inhibitor to learning and engaging in the exercise, as some people had never used some of the technology before. However, difficulties operating the technology did not seem to impact students' enjoyment of the SBRP exercise experience. One of the main reasons for utilising the file sharing and Google Docs technology was our desire for the exercise to be paperless. With the Volcanic Hazard Simulation (Dohaney et al., 2015) we found that printing resources was both time consuming for the instructor, as well as wasteful. File sharing and Google docs also allow for real time collaborative work. Combined with the fact that most participants are faster in typing than writing, the use of technology thus increased the efficiency and effective time use of the SBRP.

Google Earth is used to visualise data and is an authentic tool used in earthquake science. It is used extensively in teaching and the profession of geology. From observations, most students did not struggle with using the files (loading, viewing, saving, exporting). However, some struggled with more sophisticated tasks such as data manipulation. The use of PowerPoint as the main vehicle for delivery made it easy to use for instructors, and for students to understand, because of PowerPoint's ubiquitous presence in tertiary teaching environments. However, both researchers and instructors underestimated the time necessary to set up the technology for the SBRP, and this thus needs to be organised well in advance to ensure a smooth running of the SBRP. In terms of mitigating student issues, it is important that instructors know in advance what the students' capabilities with technology are. We found that pairing less confident / able students with more experienced ones worked well. From classroom observations, this happened spontaneously anyway, without instructor or researcher prompting.

5.4 Team Dynamics

Students reported being positive about, and learning a lot about, teamwork as part of the SBRP (Appendix 1B). Not all iterations had multiple teams in place (some had 1, others had 2 teams, see Table 1). From our observations we identified that some teams worked better than other teams. Feedback from engineering and tectonics students showed more emphasis on team dynamics, whereas emergency management students' feedback did not. This may in part be due that the 400 level hazard and disaster management students already having extensive team work in their curriculum, and may also be due to the fact these students have self-selected into a programme of study that is very interdisciplinary by nature, and relies heavily on interdisciplinary teams on a daily basis.

Appendix 1B shows that groups from which there was a lot of feedback on team dynamics barely mentioned communication in their learning feedback. We suspect that this might be due to focusing on the content of the presentation, rather than the communication of the content. Students in all iterations mentioned that they would try and do better communicating as a team in the next exercise. This signals their understanding of the importance of teamwork (and inter-team communication) and their realisation that they need to actively work on that to improve.

Teamwork was an integral part of the SBRP design for two reasons. First, teamwork is authentic and ubiquitous in virtually all workplaces and professions, and students entering the workforce need to be prepared for this. Teamwork also allows for a greater level of customisation of the SBRP. The different student groups had different learning outcomes which required slightly different setups in the exercise. For example, the tectonics and engineering student groups had a much stronger focus on the science aspects of the SBRP than the hazard and disaster management students. It is important for instructors to do as much as possible to minimise team dynamic problems and avoid dysfunctional teams, whether that is through self-selection of teams, assigning teams, or otherwise (this will depend on the classroom socio-dynamics to an extent). We found that good team leaders are crucial to the smooth running of the SBRP. To determine which students would be most suited for those roles, we used a role questionnaire (Dohaney et al., 2015) to examined student interests and strengths and weaknesses.

Students recognised that the team structure was crucial to enable quick decision making, but noted that "It was difficult to communicate about all of the information we were receiving between the two groups. We both had a large amount of information and wanted to share with each other." (Gen version, it0). As found for the Volcanic Hazard Simulation, we found that the choice of team leader is crucial. We observed several instances where the team leader role was occupied by the most senior / advanced person, and that this in some cases inhibited team dynamics. Power differentials appeared to play a part, as would the simple fact that technical proficiency in an area is not equal to sound leadership skills or capabilities. As a broad generalisation, we found teams of students from Hazards and Disaster Management tended to function very well. We suspect that this is due to the fact that the HAZM curriculum already contains substantial group assignments, and students have experience to focus on the task, rather than on team dynamics, task delegation, and logistics.

5.5 Authenticity

'Communicate the Quake' is built around authentic roles, teams and responsibilities and most instructors felt the exercise was realistic (Appendix 1C). Some students reported that the SBRP improved their knowledge of emergency management concepts, showed them the challenges that accompany such stressful events, and got them to think about career options in this important field. One student noted: "I have learned how hard it is to manage an area that has just undergone a natural disaster and the difficulties that both scientists and policy makers have when making any decisions" (General theme, it0).

At a curriculum development level, the exercise should mimic real life, but they should not inhibit the learning tasks, so they often require some alteration (i.e., depicting 'near real-life' experiences). The most common aspect of this in our SBRP is with some of the roles, which would represent entire units/sub-units within the Civil Defence and Emergency Management Structure (Ministry of Civil Defence & Emergency Management, 2013) but are simplified for easy use in the classroom.

When we ran the SBRP with it5 (emergency management professionals), there were mixed results in terms of reported levels of realism. Some participants and instructors reported that they did not feel the roles were realistic, as they did not reflect exactly the responsibilities of the roles in the workplace. For example, one of the tasks is for a media release to be written after the first earthquake event. The PowerPoint instructions asked for the entire team to write the media release together, so that all participants can work together to compose and optimize the right message. This was done because our previous research showed that students who actively participate in the communication tasks have the highest gains in communication confidence (Dohaney et al., 2015; Dohaney et al., in prep).

However, in real life, specialists from public information management (PIM) within CDEM would be entirely responsible for media releases (i.e., matching the New Zealand Coordinated Incident Management System (CIMS)). During the exercise, this resulted in several, more experienced participants advising the entire group to only let the PIM people take on this task. Some of the invited instructors agreed with this, leaving the majority of the team to have no input in this aspect, and limited opportunity to practice this aspect of communication for the majority of participants.

Authenticity is important for creating a believable, immersive scenario and for students to learn the basic roles and responsibilities, but overall we feel that a SBRP exercise doesn't have to be 100% authentic to achieve its learning goals. As shown in section 3.1, replicating the emergency management structure is not part of the learning goals. The mistake made was that we did not explicitly communicate this prinicple with the instructors and participants prior to the event, and that they should "suspend disbelief" slightly when working with participants who are accustomed to working in the professional environment. A suggestion from an instructor was to modify the roles for emergency management professionals in the scenario, so all are assigned to the public information management roles. However, we feel this would lessen the intercommunication aspects, and also lessen the specialization that occurs when people get to research and play-out their role (i.e., the SBRP would lack some of the fundamentals of role-play). Further work on adapting 'Communicate the Quake' to working professionals will need to be done. Through our follow-up work with the Earthquake Commission and QuakeCoRE to bring the SBRP to practicing emergency managers around New Zealand, we anticipate to get better insights as to the range, breadth and depth of such adaptations.

6. Phase 2: Communication Research - Results and Discussion

Section 6 includes results from pre- and post-surveying of communication measures (i.e., experience (Section 6.1), confidence/efficacy (6.2), and perceptions (6.3)) and associations between the measures (6.4). We will describe and discuss results within each subsection, and propose implications and impact to learners in Section 7. Iterations 4, 5, and 6 were made up of different students, classroom contexts and interventions (i.e., facilitation, team dynamics, and exploration of tasks, etc). The treatment of students within each of the iterations was slightly different. Notably, iteration 4 included a detailed, 1-hour lecture about the best practices of science communication, while iterations 5 and 6 had access to this lecture, as a reading, but were not given this material explicitly. Iteration 5 ran on a shorter time frame, and with very different team structures. We remind the reader that we use the abbreviations it4, it5, and it6 for these iterations to facilitate reading.

6.1 Communication Experience

Figure 4 shows the communication experience (CE) scores (out of 56 maximum) for SBRP iterations 4, 6 (students), and 5 (emergency management (EM) professionals). As can be seen in the figure, there are some clear differences between the students and the EM professionals. EM professionals had a statistically higher median score of total communication experience (Kruskal-Wallis test; H(chi2)=6.69, p=0.03), but spanned a similar range to the students.

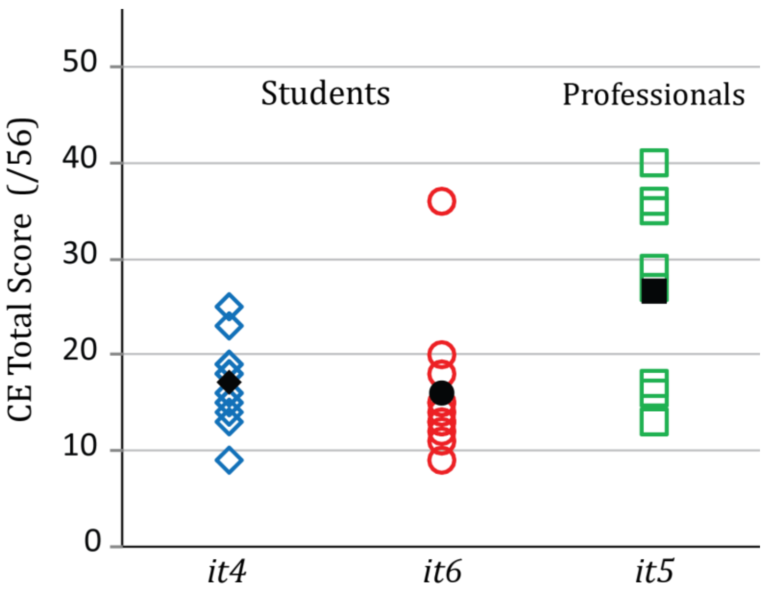


Figure 4: Communication experience (CE) survey results

We examined the constituent parts (i.e., the different communication tasks) of the CE survey, which can be seen in Figure 5. The EM professionals scored higher in all categories apart from the Performing Arts. It5 had statistically different medians for oral presentations (Kruskal-Wallis test; H(chi2)=8.01, p=0.02) and speeches (H(chi2)=7.23, p=0.01).

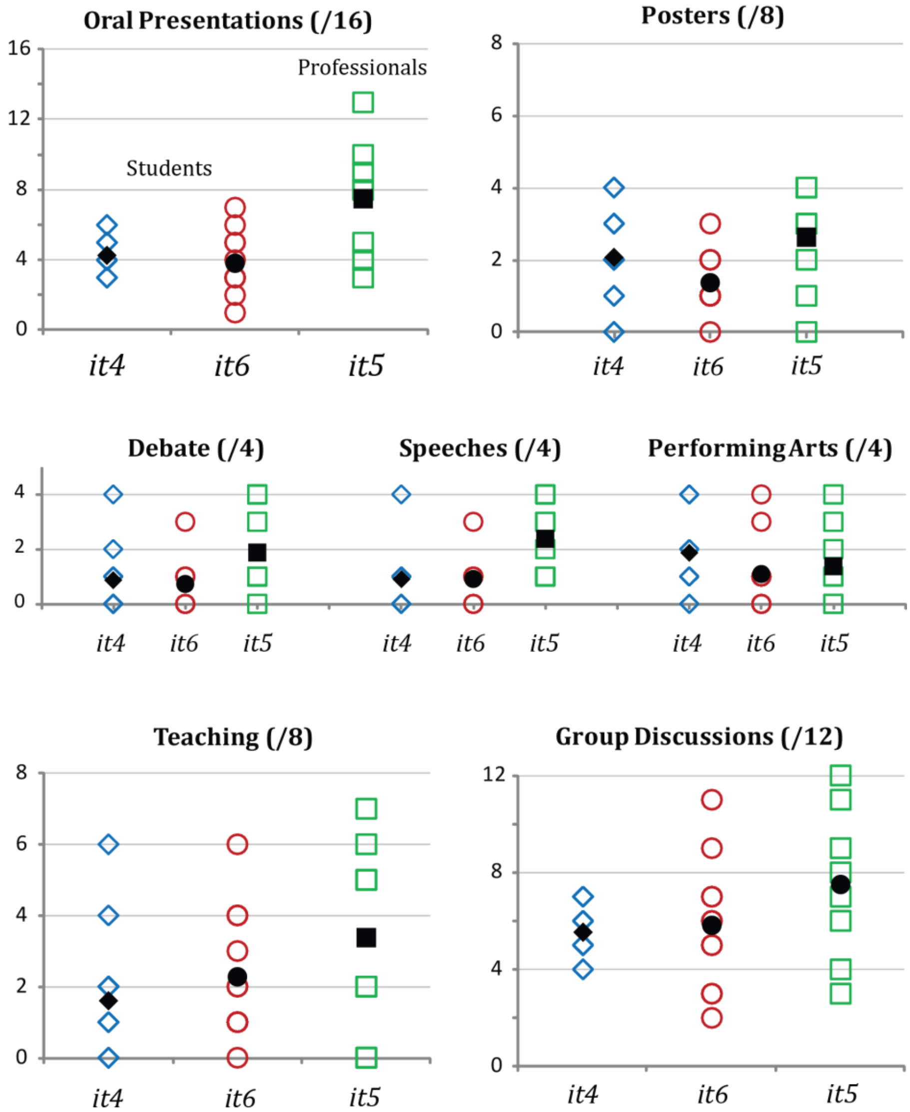


Figure 5: CE results broken down into specific communication tasks

The maximum scores of the communication tasks differ according to how many statements were asked within each category (1 question results in a possible score of 0-4, 2 questions results in a possible score of 0-8, and so on).Oral presentations and speeches showed distinct differences, on average, between the EM professionals and the student groups (it4 and it6). Performing Arts appears to be the same for all groups.

Within the overall CE scores, we explored various demographic factors to try to explain these observed differences. We examined group differences for age, gender, nationality, whether participants were currently enrolled at university, education level, and whether they had English as a first language. Participants who were not currently enrolled at university (i.e., the EM professionals) showed statistically higher CE scores

(Mann-Whitney test, Z=-2.02, p=0.04). Age is the most obvious difference between the EM professionals and the students. However, upon inspection, we found a very weak, not statistically significant positive correlation between age and CE score (Spearman's rho=0.11, p=0.55). Looking at the group differences within the communication tasks (Figure 6), we found that oral presentations (Spearman's rho=0.8, p<0.001) and speeches (Spearman's rho=0.4, p=0.01) had strong, positive, statistically significant correlations with age. Debates, group discussions and teaching all showed weak positive correlations but were not statistically significant.

These results indicate that oral presentations and speech experiences increase with age and life experience, resulting in increased overall communication experience (by our defined measure). Interestingly, these are both oral, public speaking tasks. However, there may be a selection bias, as the older participants which we sampled are working within an employment sector (i.e., emergency management) which typically requires adept communication skills. It is not likely that all of our students will pursue emergency management careers, so larger and randomised sampling in the future will allow us to explore this association further.

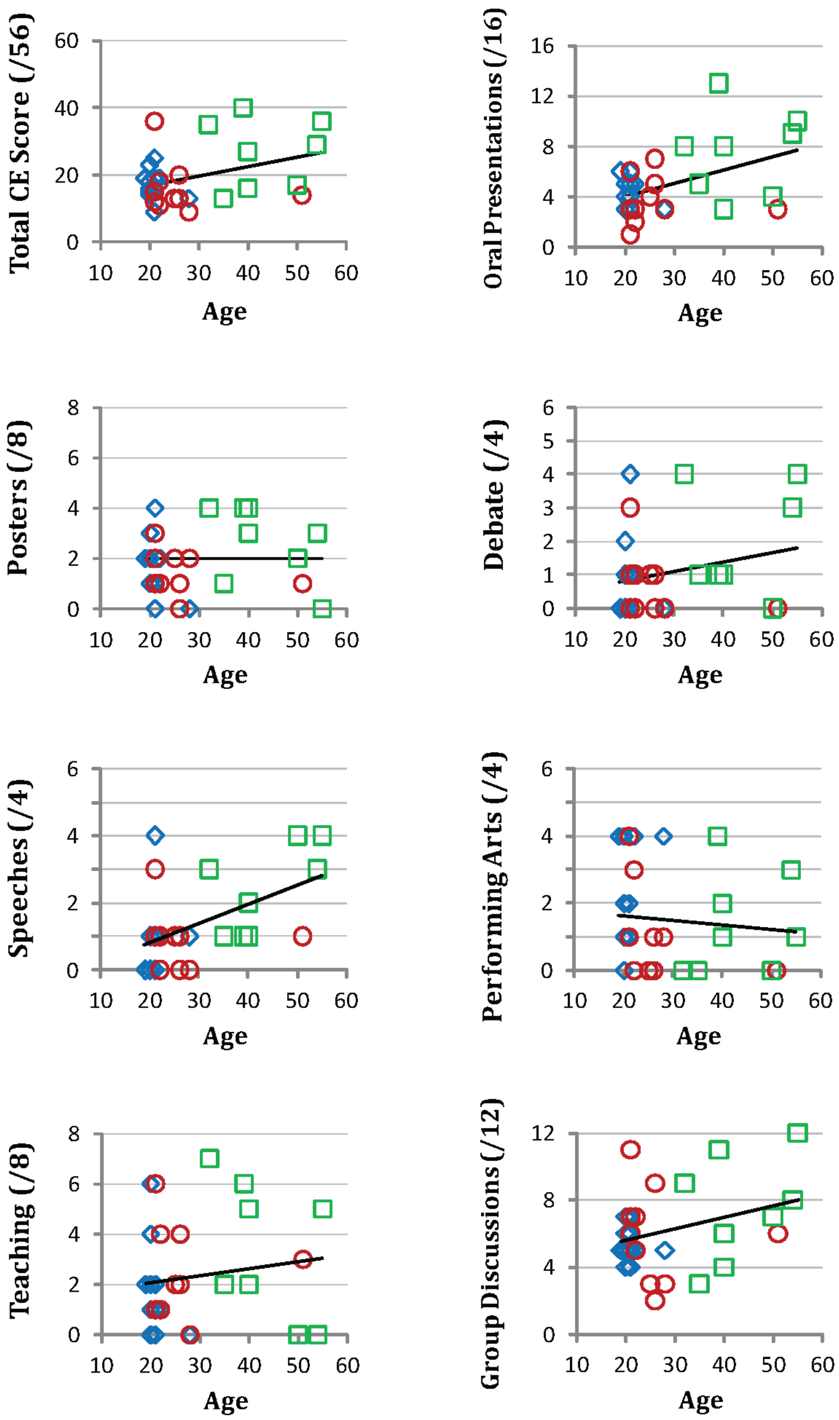


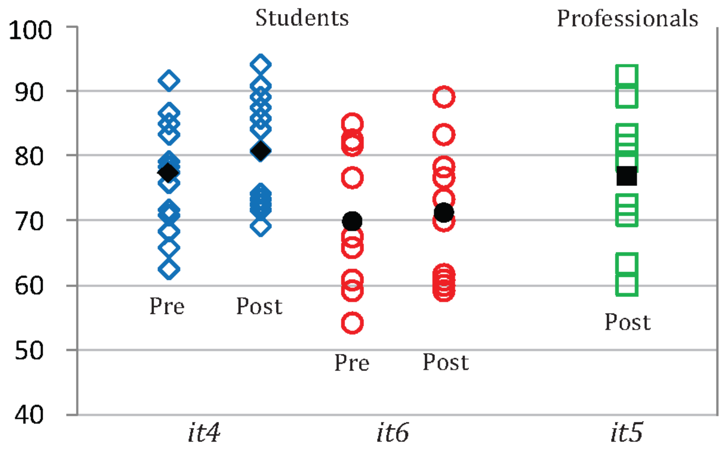
Figure 6: CE scores compared with age.

Most communication tasks showed positive correlations with age, except for posters (no relationship or trend) and Performing Arts (negative relationship).

6.2 Communication Confidence

Figure 7 shows the results from the pre- and post-exercise SPCC. Figure 7A compares the scores between the iterations (4, 6 (students), and 5 (EM professionals)) showing that all groups have similar post-SPCC results, with it6 showing a slightly smaller mean score (71%, compared with 77% it5, and 81% it4), though these differences were not statistically significant (One-way ANOVA, F=2.79, p=0.08).

A. SPCC Results



B. Individual students changes

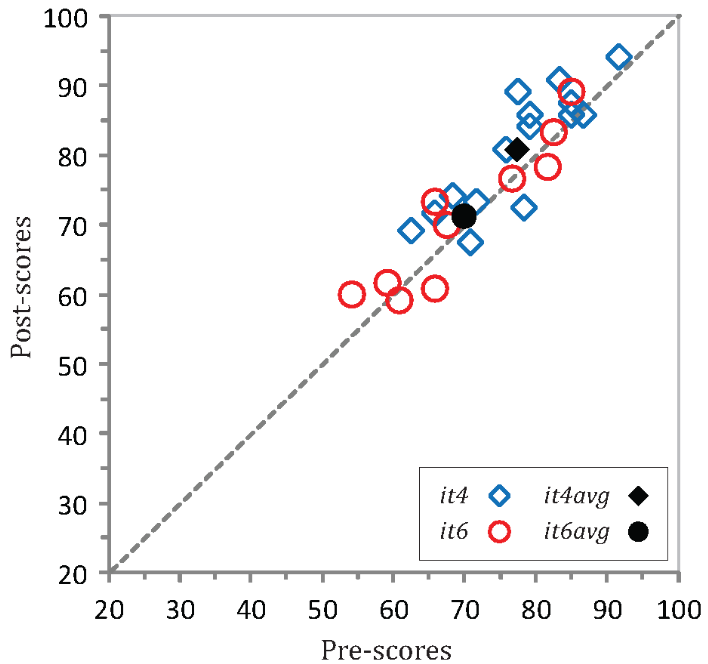


Figure 7: Self-reported perceived communication competence (SPCC) survey results

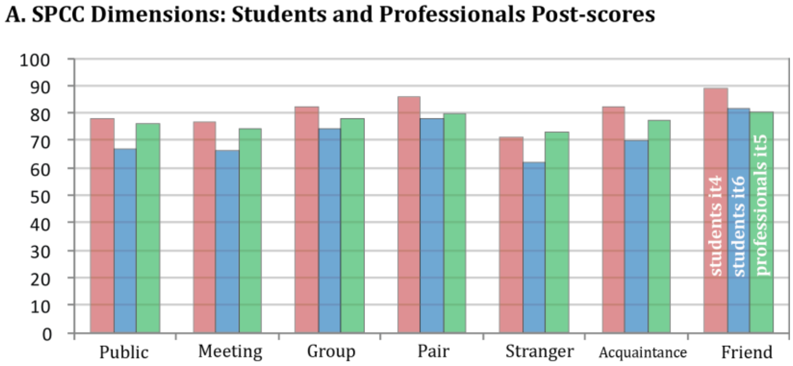
Average values for each cohort are shown by the black symbols. (B) Plot of pre- versus post-scores showing individual student changes. The dashed line represents a 'line of no change' (i.e., students above this line have positive changes of communication confidence, while students below this line had negative changes). Note that most of the individual students (18 students) had positive changes in confidence.

SPCC pre-scores were checked for possible factors which predisposed participants towards low or high communication confidence. As shown in Figure 7A and B, it4 had higher pre-scores than it6, though this was not statistically significant. The pre-tests were checked for exercise iteration, gender, age, nationality, and year of study. Nationality was the only factor which elicited statistically different pre-scores. US students had statistically higher pre-scores than NZ students (78% versus 69%, unpaired t-test, t=2.39, p=0.03). "Other" nationalities were removed, as there were only two students in this category. It4 was made up of predominantly US students, which explains the differences shown in Figure 7A.

The SBRP exercises involved students from New Zealand, the US (via overseas exchange programmes), and Canada. All of these countries have differing cultural norms, attitudes, and approaches to learning. Previous research by Dohaney et al. (2015) looked at pre- and post-SPCC scores in US and NZ students, after the Volcanic Hazards Simulation, but found no connection between nationality and communication confidence. In particular, some cultures have been documented to have negative feelings towards high achievers (i.e., 'tall poppies'; Feather, 1994), which could be connected to self-reports and public speaking. Therefore, it is not unreasonable to assume that students' communication confidence is at least in part influenced by cultural norms. Instructors should be aware of their students' nationalities and whether it predisposes them to lower or higher confidence, those groups may require customised support and facilitation when participating in these exercises.

Overall, the mean change (post-SPCC minus pre-SPCC) was positive (mean of 2.6 ± 4.3), with predominantly positive changes for individual students (i.e., scores lie above the 'line of no change', Figure 7B; it4 = 12 positive changes, 3 negative changes, it6 = 6 positive changes, 1 = no change, 3 = negative changes). A paired t-test of individual pre and post-scores showed the differences to be statistically significant (t=-3.00, p=0.006). There was no relation between demographics or curriculum factors (iteration group, teams, whether the student spoke in public speaking tasks) and either a positive or negative SPCC change. In addition, we did not find a correlation between pre-scores and change. This means that the benefits of the SBRP on communication confidence is independent of a student's initial communication confidence level.

A breakdown of the SPCC instrument into communication contexts and receivers (i.e., audiences; Figure 8) shows differences between the iteration groups (Figure 8A), though these differences were not statistically significant. It is worth noting here that the emergency management professionals (older and with reported higher levels of experience, Section 6.1) did not have different levels of confidence in different contexts or to different receivers. This is a surprising result, as we expected participants' confidence to increase with age and experience. Comparison of communication contexts and receivers between pre and post-SPCC scores for it4 and 6 is shown in Figure 8B. The largest positive shifts are observed in the public speaking, meeting, and stranger (i.e., unknown member of the public) categories, which are all emphasised by the learning goals of the SBRP. These results indicate that the exercise was successful in targeting specific contexts and audiences and improving students' confidence when communicating in these situations.



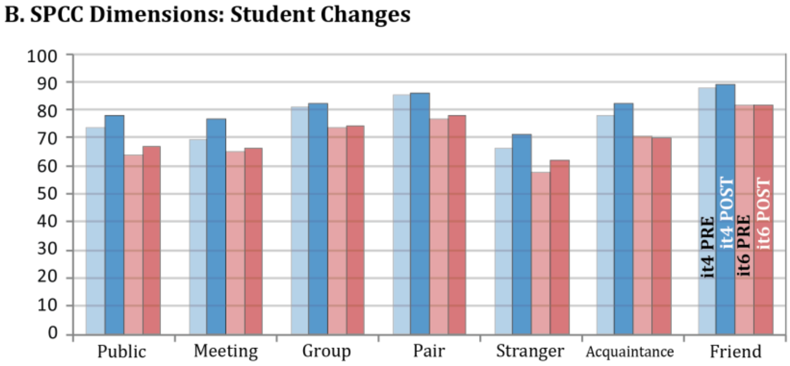


Figure 8: SPCC results broken down by communication context and receiver

(A) Bar chart comparing students' and professionals' post-SPCC scores for specific communication contexts (public, meeting, group and pair) and communication receivers (stranger, acquaintance and friends). (B) Bar chart showing changes between students' pre- and post-SPCC scores for specific communication contexts and receivers. Both groups of students increased their confidence in most dimensions.

6.3. Perceptions of Crisis Communication

6.3.1 Overall Results

The perceptions survey (Appendix 3) assesses students' attitudes to science communication with the public during an earthquake crisis. Student responses that agree with experts are listed as 'favourable' (%F out of all responses in the figures), and student responses that disagree with experts are listed as 'unfavourable' (%U out of all responses in the figures. Figure 9 shows the participants responses grouped by iteration. A comparison of the post-scores, showed that iteration 4 had a higher mean (80.3 ± 7.3) than it6 (71.8 ± 9.6) and it5 (EM professionals; 74.2 ± 10.5), though it was not statistically significant (ANOVA, F=2.99; p=0.06).

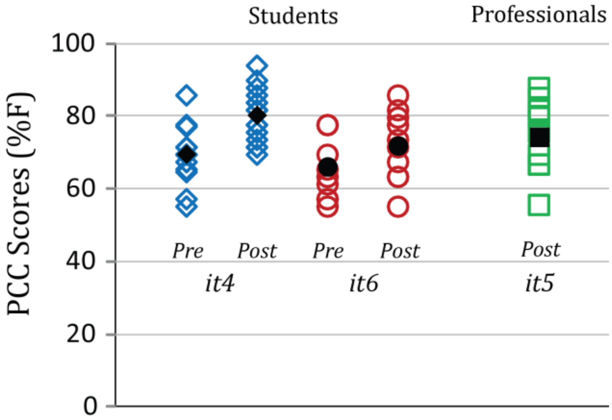


Figure 9: Perceptions of crisis communication (PCC) survey results

Note that the professionals scored similarly to the student groups.

Available pre-scores from it4 and it6 were checked against demographic information (previously mentioned) allowing us to determine if there were factors that predisposed participants to having lower or higher perceptions. A look at age versus the pre-scores revealed that participants who were 23 or older (n=6, mean=62.3) and <23 (n=19, mean=70.1) revealed a statistically significant difference in perceptions with the older students revealing less expert-like perceptions (unpaired t-test, t=2.21, p=0.04; Cohen's d=1.17 (commonly accepted as a "very large" effect size)). A t-test comparing the post-scores (including the EM professionals; 23 or older (n=15, mean=72.2) and <23 (n=19, mean of 79.4)) also revealed a statistically significant difference where older participants had lower post-test PCC scores (t=-2.37, p=0.02, Cohen's d=0.82 ("large" effect size)). These findings are surprising. It is likely that these two groups have been exposed to different attitudes towards communication during their education, work, and life experiences. However, we do not know what has caused lower perceptions in older participants. Further research will assess the possible relationship between age and perceptions. A detailed look at specific statements (below) will allow us to determine which aspects of crisis communication may be more or less expert-like.

It4 and it6 were assessed for changes in scores (Figure 10A and B). All students in it4 and 6 achieved positive changes in perceptions, aside from one student whose scores did not change. A paired t-test of the post and pre-SPCC scores, showed significantly different (t=-7.76, p<0.001, Cohen's d=-1.00 ("large") scores after the SBRP. Also, the changes achieved by it4 was statistically significantly higher (mean=10.7 ± 6.0) than it6 (mean=5.7± 3.4) (Unpaired t-test, t=2.38, p=0.03; Cohen's d=1.02 ("large")).

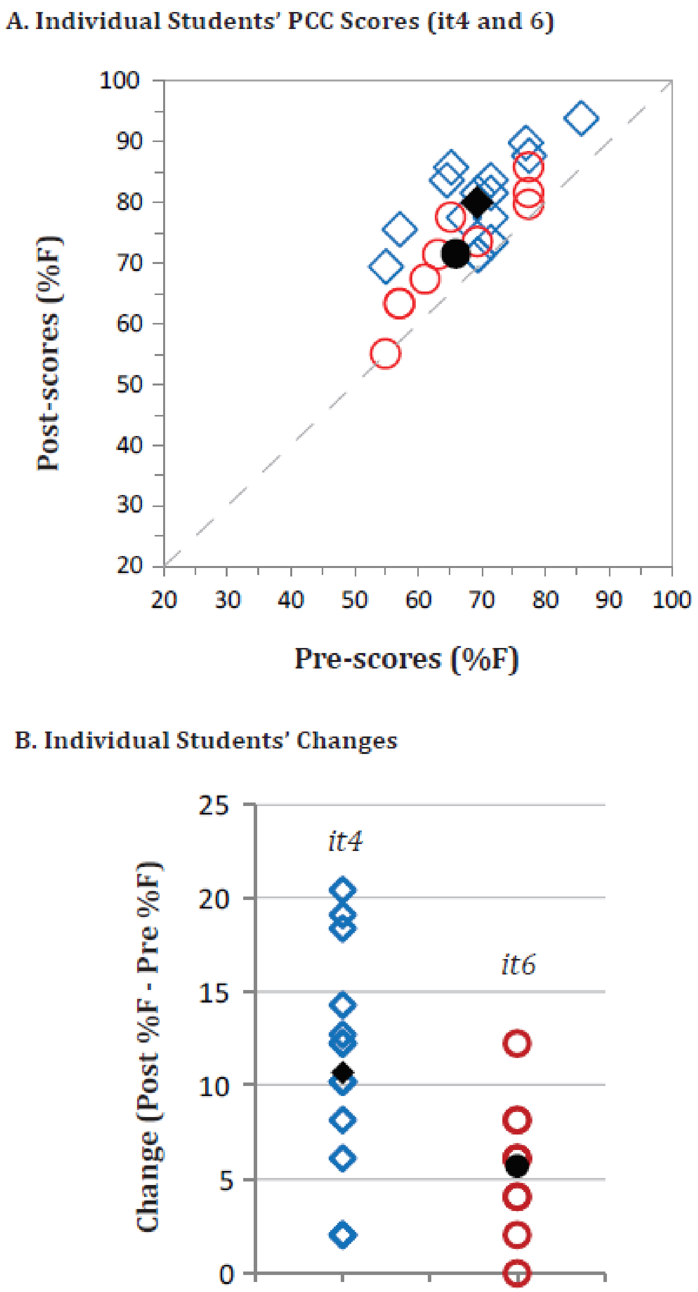


Figure 10: PCC results showing individual student changes

(A) Individual students' PCC Results from it4 and it6. It4 students shown with blue diamonds; it6 with red circles. Mean scores for each group are in black, filled-in symbols. Note that all of the individual students' scores are positive, plotting above the line of no change. (B) Bar chart showing individual students' PCC score changes from pre- to post-survey. It4 achieved higher changes.

Changes (iteration 4 and 6) were examined for demographic (as stated above) and curriculum factors (e.g., iteration, teams (CDEM vs SAG), direct participation in public speaking tasks (Y, or N)) which influenced their change in perceptions. We found that US students had a statistically higher mean change (mean=10.7 ± 6.2) than the NZ students (mean=5.67 ± 3.65) (unpaired t-test, t=-2.21, p=0.04; Cohen's d=1.00 ("large") and that the 300-level students (mean= - 10.0 ± 5.8) achieved higher mean change than 400-level students (mean= - 5.7 ± 3.4) (unpaired t-test, t= 2.07, p=0.05, Cohen's d=0.90 ("large")).

The SAG team students (science-advisory) had higher means (11.1 ± 5.1, versus 7.4 ± 5.6) than the CDEM (emergency management) students, though it was not statistically significant (t=-1.67, p=0.11, Cohen's d=0.71 ("medium")). Students who directly participated in public speaking tasks had higher mean change (9.8 ± 5.7) than those who did not (4.5 ± 2.7). Though this result was not statistically significant (t=1.99, p=0.058), it had a very large effect size (Cohen's d=1.19).

Based on the inherent properties of the students within each iteration group, there was some overlap between the demographic factors, curriculum factors and the treatment received by each iteration. It4 consisted of US students, in 300-level while it6 consisted of NZ students at the 400-level. We had planned to run more SBRPs with a broader range of demographic and academic backgrounds, but that was not logistically feasible. More research is needed to determine whether changes in perceptions are truly affected by these specific curriculum factors or demographic factors, or whether it is a data artefact resulting from properties of the student population within the iterations. This will become clearer in the coming years as we continue to use the SBRP in different contexts.

6.3.2 Individual PCC Statements

Appendix 5 shows the PCC responses broken down by statement, including statistical information. As in the previous section, the scores indicate percentage agreement with the experts (section 4.3.4), before and after participating in the SBRP. As can be seen in the appendix, there is a wide range from disagreement to agreement with experts on the statements. Some statements had (almost) perfect agreement with experts (43, 44, 47), other medium (i.e. ~50%, 7, 22, 26), and others had low agreement (<50%, 19, 33). It is interesting to note that in some cases, low student agreement with experts was on items that the experts themselves had differing opinions on as noted in section 4.3.4 (2, 3, 8, 33, 35, 45). Also interesting to note is that on a number of statements the it5 participants (the EM professionals) had different post scores than it4 (US students) and it6 (New Zealand students). Three of those differences were statistically significant: statements 1, 17, and 40. It6 students showed statistically significant differences in post scores from the other groups on statements 3, 31, 32, and 39. We also tested for differences between pre- and post-scores (i.e., Changes) for it4 and 6 (recall that it5 had no pre data available). None of the negative changes we found were statistically significant. On the other hand, statistically significant positive changes were found for statements 3, 7, 9, 10, 11, 15, 16, 22, 27, 31, 37, and 42. Below, we discuss the responses to some of the statements in more detail.

We were encouraged, but not entirely surprised, to see high levels of agreement with experts on statements 15 (*communication should be used to build trust between the scientist and the community*) and 47 (*to be an effective communicator, you need to practice your communication skills*). Building rapport with stakeholder audiences is crucial to building trust and for the communication to be successful. This requires considerable practice. For trust to be built, it is important that the stakeholder feels a part of the communication, not just a recipient. Statement 7 (*communication should be in* *the form of a dialogue*) probed this further. All three groups had medium range post-scores on this item, but both students groups had a positive change (statistically significant for it4). Science communication research (which says that 'dialogue is good'; Fischhoff, 1995; Fisher, 1991) is often not accessed by practitioners (Miller, 2008), so it is possible that in the New Zealand setting, some of these ideas have yet quite made it into practice. SBRP requires and endorses this type of communication (e.g., group and panel discussions).

The goals of the communication was explored in statement 1 *(help people understand why earthquake has occurred)*. EM professionals had lower agreement with experts compared to the students. Their role is primarily concerned with management of an emergency, and perhaps they feel it is not necessary to explore the 'whys'. However, we remind the reader that our expert group contained more scientists than emergency managers, which may have slanted the expert group opinion in a certain direction.

The question of how much information should be included in your communication is always an interesting challenge (Statement 2; *be comprehensive (i.e., include all the scientific aspects discussed behind the scenes))* and the expert responses were mixed, though the overall result was 'disagree'. Experts who had more experience as a professional communicator had more neutral responses, whereas less experienced people leaned more towards 'disagree'. It was clear from the responses that being comprehensive should not be at the expense of clarity. As one expert stated: "The desire to be comprehensive should not interfere with the need for clarity and conciseness." All SBRP participant groups had medium to high agreement with experts on this topic. One student stated: "Keep your communication simple with no fluff, often the excessive details are unnecessary and distract from the overall purpose of the task" (Tectonics version, it1). Similarly, statement 17 *(not include information related to past crisis scenarios)* presents an interesting contrast between the EM professionals and the students. Students were much more inclined to agree with experts to put the current scenario in context. However, the EM professionals tended to disagree with them (statistically significantly so). We do not know why this difference exists, but we suspect a relation with statements 19 and 22 (see below), that there is an argument to be made that previous analogous situations are not necessarily a good predictor of what will happen in the future with regard to the current event.

The 'mechanics' of communication was explored in numerous statements. Students tended to want to minimise jargon and scientific terminology (Statement 33; *when communicating with the public it is appropriate to use scientific terminology)*. One student noted: "There is a fine balance between being too detailed and jargon-y and not providing enough detail." (Engineering version, it3). This is not necessarily an easy task. Another student noted: "It is always difficult to get enough and the right information across accurately. [You] need to be very careful in the language ... Practice doing this helps." (Tectonics version, it1). We suspect that experts may feel that the use of scientific terminology is acceptable, as long as it is explained to the audience (e.g., by using modifiers or analogies). Responses to statement 35 *(... it is appropriate to use formal terminology)* illustrate this as well. Formality can be perceived as a way to be seen as authoritative (i.e. a credible source of information), but some students struggled with this: "Finding the balance between showing some compassion and showing the cold hard facts was difficult at times." (Engineering version, it3). The display of information was probed in statements 42 *(... it is appropriate to use statistics*) and 45 *(...*

it is appropriate to use graphs). Both student groups had low pre scores compared to the EM professionals group. We suspect that student groups perceive these quantitative tools as too complicated for communication with the public. The use of different media was explored in statements 27-32 (*it is appropriate to use …. press conferences (27), radio bulletins (28), media interviews (29), websites (30), social media (31), and townhall meetings (32)*), with most groups showing high perceptions, as well as statistically significant positive shifts on items 27 and 31. We suggest that the SBRP, with its explicit use of all these different communication formats, is effective in conveying the importance of using different media to communicate with the public.

The role of emotions in communication was explored in statement 3 *(not show the scientist's emotions)* and statement 26 *(persuade people to care).* On the former item, it is interesting to note that all three groups had different post scores. The students in it4 showed a large change from pre to post (54%, statistically significant), whereas the it6 students remained reasonably low. It is worth noting that the experts did not have clear consensus on this item either. Experts with more professional communication experience had stronger disagreement with this statement than those who had less experience. In contrast, the students in it6 showed a statistically significant improvement on the latter item. Whether these changes are due to the exercise or to demographics is not clear.

Statements 19 *(avoid describing a worst case scenario)* and 22 *(not acknowledge sensitive or controversial topics)* wade into topics that are grist on the mill of journalists. Experts tend to agree with the former statement, while none of the participant groups do. In the latter statement, we saw a marked change in the post scores for it4 students. We ascribe this to the fact that these students received a detailed science communication lecture prior to the SBRP, which included specific points pertaining to these items, whereas the other groups did not receive this lecture. Both statements are important in particular with communicating with (mass) media, and present the communicator with an interesting conundrum. On the one hand, worst case scenarios can be considered inflammatory and induce unnecessary anxiety in stakeholders. On the other hand, as anyone who has ever been in a media conference can readily attest, it will be among the first questions one faces (Tara Ross, 2014, personal communication), and it is important to have an answer ready for a question like this. Similarly, controversial topics can and will come up in press conference venues, and a good, strong answer is imperative to avoid losing credibility.

Related to the notion of credibility is statement 8 *(acknowledge political influence / agenda on the communication).* Both experts and students struggled with this statement, with neither coming to a clear consensus. A quote from an expert scientist illustrates this: "My feeling is that science communication should remain factual and that policy decisions, advice, and empowering the public should be done by authorities and experts in hazard and disaster management, in collaboration with scientists." It is thus not clear whose responsibility it would be to acknowledge the political influence / agenda, if at all.

In light of the L'Aquila case in Italy (one of the motivators behind this entire project) the contrast in responses between statement 48 *(As a scientist, you should be accountable for the science advice that you provide)*, and statement 49 *(As a scientist, you should be liable for the scientific advice that you provide)* is very interesting. All groups had high agreement with experts on 48, who also agreed with the statement. In contrast, SBRP exercise participants generally have lower agreement with experts of liability. Experts feel that scientists should be accountable, but not liable, whereas participants think scientists should be both accountable and liable. An expert stated: “if [there is] too much fear of liability then you prevent any communication - loss of potentially important information.” Another expert stated: “Liability is a dangerous path ... but if the advice is clearly negligent, then we may actually be liable.”

6.4 Associations between Communication Dimensions

We compared the scores of the different communication dimensions (experience (CE), confidence (SPCC), and perceptions (PCC)) to one another. Ideally, we would have wanted to compare the pre-scores rather than the post-scores (as the post-scores are influenced by the effectiveness of the SBRP). However, as we do not have pre-scores for it5 participants, this is not fully possible. We used non-parametric tests to examine relationships of SPCC-CE and PCC-CE, as the CE measure is ordinal. We used parametric tests to examine the relationship of SPCC-PCC.

Firstly, we looked at possible associations between communication experience (CE) and communication confidence (SPCC). We would expect that with increased experience, the communication confidence would increase. Results show that there is a very weak positive correlation between CE and the Post-SPCC scores, but it is not statistically significant (Spearman’s rho=0.23, p=0.21), and there was no relationship between CE and Pre-SPCC scores (Spearman’s rho=-0.059, p=0.78). We examined whether specific communication tasks were associated with confidence and found that both oral presentations and speeches showed positive associations with confidence (Oral presentations: Spearman’s rho=0.16, p=0.25 ; Speeches: 0.94, p=0.014), though oral presentations was not statistically significant. However, examining the data distribution leads us to suspect that this result is an artefact of the ordinal nature of the data, rather than a real effect. Anecdotally we hear that more experience should lead to higher communication confidence, but our data is inconclusive in this regard. Further research will allow us to explore whether there is a meaningful association between these variables.

Examination of the relationship between communication experience and perceptions revealed similar findings: weak, not statistically significant, positive correlation for both communication experience (CE) and pre-perceptions (Pre-PCC; Spearman’s rho=0.22, p=0.29,) and post-perceptions (Post-PCC; Spearman’s rho=0.28, p=0.12). We did not expect a relationship between these two variables, as previous communication experience in a range of contexts and topics should not necessarily correspond to an improvement of perceptions in crisis communication.

Examination of the relationship between communication confidence (SPCC) and perceptions revealed the same: weak, not statistically significant, positive correlation for both pre-scores (Pre-SPCC vs Pre-PCC; Pearson’s r=0.20, p=0.33) and post-perceptions (Post-SPCC vs Post-PCC; Pearson’s r=0.12, p=0.51). This too is not really surprising. Confidence is one's ability to communicate does not necessarily mean that one has expert views on communicating.

Last, we compared the changes in communication confidence (SPCC) and the perceptions of crisis communication (PCC) before and after the SPRB. We found a significant positive correlation (Pearson's $r=0.47$, $p=0.019$) between changes in confidence and changes in perceptions. We interpret this as the SBRP succeeding as a communication intervention, with (positive) changes in how to communicate (i.e. a more expert view) being positively related to (positive) changes in confidence.

7. Impacts

7.1 Summary and Impact on Learners

Phase 1 of the research was concerned with building and optimising a design of a Scenario-Based Role-Play. Our previous research on the Volcanic Hazard Simulation (Dohaney et al., 2015) helped to solidify the format and assessment of the SBRP. We aimed to take the existing design model and adapt it to meet several new criteria:

- Building the new scenario
- New classroom context
- Build new and customised measures
- Work with new instructors and new groups of learners
- New focus on communication (i.e. new learning goals and outcomes)
- New integration of social media and publicly available data sets

Observations and questionnaire data from instructors and students showed that the iterative design approach of the SBRP was flexible and robust, and was able to deliver the diverse learning outcomes that the different instructors required for their respective classroom environments and course learning objectives. For those readers interested in building an SBRP themselves, we would refer them, besides this report, to Dohaney et al., (2015), the Volcanic Hazards User Manual (Dohaney et al., 2014), and the Communicate the Quake User Manual (Dohaney et al., in prep.) which is available from the first author and will be available online in the near future through the Ako Aotearoa website.

The ongoing success of the SBRP depends on the willingness of instructors and institutions to (continue to) use the materials and adapt it to their needs. This comes with some logistical challenges and time investment. However, as our data has shown, the SBRP experience for students (and instructors) is positive (as we illustrated briefly in section 5.5).

The beginning of phase 2 was focused on developing two instruments (communication experience, and communication perceptions). Our priority in this report was on the experience, confidence, and perceptions of communication, and their inter-relationships.

We collected a wealth of qualitative and quantitative data (Table 3) to measure the broad concept of communication performance (Figure 3). In the next years, we will delve deeper into the data (in particular the vast amount of qualitative data) to paint a richer picture of communication performance.

Learners have benefitted from building on previous experience, improving their communication confidence and perceptions of crisis communication. Additionally students reported gained knowledge and skills in line with the learning goals of the exercise.

7.1.1 Experience

Results from the experience survey indicate that students and EM professionals had different communication experiences, in particular public speaking tasks such as speeches and oral presentations. This was correlated with age. Both results are not surprising, and are consistent with the job description of EM professionals. It is common for university level courses (in particular lower enrolment courses at the upper division) to include oral presentations and group discussions, where students have the opportunity to practice communication skills. However, most courses don't practice a range of authentic communication tasks as encountered by practicing emergency management professionals and science communicators, such as panel discussions or radio bulletins. Our SBRP provided the opportunity to not only practice known skills, but also to practice novel skills needed in the modern digital communication era, such as instant-feedback social media. For example, SBRP participants were asked to respond to questions from the general public on Twitter and participate in the online discussion.

7.1.2 Confidence

Overall, there was a statistically significant change in participants' confidence to communicate. Additionally, for the groups in this study (iteration 4-6) there was a weak positive, but not statistically significant relationship between communication experience scores and communication confidence. This is surprising as we had hypothesised that people with more experience should have more confidence.

Nationality was an interesting factor. US students had statistically higher pre-scores than their New Zealand counterparts. We briefly discussed this in section 6.2.

The majority of students (18/25) showed positive shifts in confidence but several students reported negative shifts in confidence. We conclude that even with customised versions and different learning outcomes of the SBRP, the SBRP is able to generate a positive communication confidence shift. It was also independent of the role the student had in the SBRP. This is interesting because some of the roles, such as the team leaders for the emergency management and science advisory group, had a higher communication load on them than other participants. Interestingly, we also found that the SPCC changes we observed over the course of a single, multi-hour intervention were on par with changes observed in the literature for interventions that have a much longer time frame (Rubin, Rubin & Jordan, 1997).

7.1.3 Perceptions

All students had positive changes (i.e. more expert-like in their thinking) in the perceptions from pre-post (statistically significant). We consider student shifts in perceptions to be more expert-like as beneficial to their overall competence as science communicators. We think that these shifts in perceptions are important to start building a community of early-career science communicators. Both participants and experts struggled with similar individual statements on the perception survey. In our opinion, the fact that there is disagreement on the statements signals the inherent complex nature of science communication, rather than a psychometric property of the statement item. It would be ideal in the future to get a broader sample of experts, from a more diverse range of (academic and social) cultures, to investigate this further.

Ultimately, the SBRP is effective at changing students' perceptions and in changing students' confidence, regardless of students' previous experiences and their initial perceptions or confidence levels.

7.1.4 Debriefs

Results from student and instructor debriefs (Appendix 1B and 1D) indicate that students had engaging and challenging experiences communicating about earthquakes to diverse stakeholder audiences. Students reported the SBRP to be challenging, but also noted that it was a very positive learning experience, identifying learnt emergency management/response and communication skills and knowledge that are in line with learning goals. Students became more aware of the importance and complexities of communicating earthquake science and emergency management information. Instructors also noted that students succeeded in communicating and noted the authenticity of the exercise, but also noted the importance and need for students to prepare adequately for their roles.

7.2 Impact on Teaching Natural Hazards and Disaster Risk Management in New Zealand

Disaster resilience is a key focus for New Zealand (CDEM Act 2002), particularly in the aftermath of the Canterbury Earthquake Sequence (Kaye, 2015). Effective communication between technical experts and other stakeholders has been identified as a major focus in the multi-lateral United Nations Strategy for Disaster Risk Reduction, known as the Sendei Framework for Disaster Risk Reduction 2015-2030 (UNISDR, 2015). The Sendai Framework and the New Zealand Civil Defence and Emergency Management framework explicitly supports a dialogue model of communication (in contrast to a transmission model), encouraging public, private, and academic sectors collaborate in a 'people-centred' approach to disaster risk reduction (UNISDR, 2015). This requires different professional stakeholders to communicate clearly with one another, respect each other's expertise and (professional) cultural backgrounds when operating in the integrated, multi-disciplinary environment of disaster risk reduction.

However, New Zealand (and international) natural hazard scientists, earthquake engineers and emergency managers, frequently lack knowledge of broader communication pathways and the skills to communicate and critically think about natural hazard risk and disaster management, particularly during crisis periods (such as the Canterbury Earthquake Sequence) (Gluckman 2014).

Our SBRP is aligned with the dialogue model of communcation and we have developed a tool and broader knowledge framework which aims at addressing the need for advanced university students in geology, engineering, and emergency management to become familiar with, and able to work in, this internationally favoured diaglogue model. As we have seen, participants reported an appreciation of the challenges of communicating science advice, and a demystification of communication to experts and to non-expert audiences. Additionally, participants comment on the authenticity of the simulation and describe that the role-play has increased their understanding of their respective roles and responsibilities (which as stated were modelled after real science and emergency management roles). This positions the SBRP as a valuable contribution to the New Zealand natural hazard, earthquake engineering and disaster risk reduction sector(s).

'Communicate the Quake' builds off of the successful volcanic hazards simulation (Dohaney et al, 2015), which has been adopted by Universities of Canterbury and Auckland in their post-graduate teaching programmes, the DEVORA project (a multi-institutional, inter-disciplinary, multi-million-dollar science collaborative programme aimed at reducing volcanic risk in Auckland, see http://www.devora.org.nz), and associated use for training by the Auckland CDEM Group. We hope to emulate this success by taking a key next step to extend and maximise the value of the research and resources for New Zealand end users, focusing on two activities:

a) Outreach: sharing research findings from this project (e.g., communication assessment tools) with relevant practitioners and tertiary educators in the natural hazard sector;
b) Capacity and capability building: training practitioners and tertiary educators in the use of the role-play as a teaching tool.

This can be achieved through a range of relationship and network building activities prior to a crisis, which will help to enhance their understanding of each other's roles, needs and responsibilities during and event (Doyle, Paton & Johnston, 2015). At the time of writing this report (April 2016), the outreach and capacity and capability building work has started, supported by the Earthquake Commission and QuakeCoRE.

8. Conclusions, Lessons Learned and Future Work

8.1 Conclusions

The “Communicate the Quake” scenario-based role-play was successfully designed and developed in the first phase of the study, in close consultation with instructors and students who provided valuable comments and feedback. The SBRP provides an authentic, immersive experience that can serve a variety of learning outcomes in courses in hazards and disaster management, earthquake engineering, and the geosciences. The SBRP provides an environment in which participants can practice a variety of communication formats and to a variety of stakeholders. Both students and instructors agreed that the SBRP is challenging, but also reported that it was a very rewarding and useful exercise.

Using our communication experience instrument (validated and developed for this study), we showed that emergency managers in it5 brought a different set of experiences to the SBRP than students did; in particular they had more experience in oral communication tasks such as speeches and presentations. Such information is useful for instructors to be able to emphasise or de-emphasise certain tasks within the SBRP to achieve optimal learning goals.

Using the SPCC instrument (an existing validated measure), we found that US students had statistically higher pre-scores than NZ students, indicating that a student’s cultural background may influence their communication confidence. Overall (on average) experience resulted in positive changes with most students achieving positive and statistically significant changes. These changes were independent of pre-score. This indicates that the SBRP is successful at positive changes in communication confidence, regardless of previous confidence levels. The largest positive shifts are observed in the public speaking, meeting, and stranger (i.e., unknown member of the public) categories of the instrument, which is encouraging as these dimensions are explicitly emphasised in the SBRP.

Using our perceptions of crisis communication instrument (developed and validated for this study), we showed that the SBRP was successful in positively, and statistically significantly changing students’ perceptions. Several factors appeared to influence the amount of changes achieved such as nationality, their year of degree programme, and the team (i.e., CDEM vs. SAG) which they participated in.

Assessment of individual statements (49 statements in total) from the PCC instrument showed that there were items in which most student groups agreed with experts (‘high perceptions’), and others where they disagreed with experts (‘low perceptions’). More importantly there were several topics which experts struggled with (i.e., resulted in predominantly ‘neutral’ responses, but with distributions leaning more towards agree or disagree) that also resulted in mixed and low perceptions from the student participants. In particular, the topics of comprehensiveness (i.e., opposite of conciseness), showing the scientist’s emotions, political influence/agenda, use of formal language, and use of graphs and plots were difficult for experts and SBRP participants alike. There were also statements which resulted in emergency management professionals disagreeing with the student groups: the ‘why’ of the crisis, discussing past crisis scenarios (i.e., context), and communication of probabilities.

To investigate any relationships between the communication proxies, we compared the scores of the communication experience (CE), confidence (SPCC), and perceptions (PCC)) to one another. Though there were no statistically significant associations between pre- or post-scores within the instruments, but we did find a positive relationship between the changes achieved in confidence and perceptions, indicating that students who experience positive shifts in confidence, also experienced positive shifts in perceptions. This means that for some participants, the SBRP was duly effective in both dimensions.

Students reported the SBRP to be challenging, but also noted that it was a very positive learning experience, providing feedback that they learnt emergency management/response and communication skills and knowledge that are in line with learning goals. Additionally students became more aware of the importance and complexities of communicating earthquake science and emergency management information. Instructors also noted the authenticity of the exercise, but also the importance and need for students to prepare adequately for their roles.

8.2 Design Research Lessons Learned

In the two and a half years that this project ran, we learned a number of valuable lessons. The first was that buy-in from instructors is absolutely essential for their engagement in the SBRP so the exercise can run properly. This means that learning objectives have to be carefully chosen and agreed upon to ensure that the SBRP can deliver on the desired outcomes. The second key lesson is related to this, and concerns the need for flexibility. The SBRP was designed to be flexible, but we overestimated the amount of flexibility that we could accommodate in the task and narrative structure of the SBRP, while at the same time underestimating the amount of customisation that people wanted. The third lesson was the value of having a postdoctoral fellow to work on the project full time. This allowed for the project to remain focused and be progressed faster than would have been possible if the project was led by a range of academics each having only a minor time contribution. In "Transforming Tertiary Science Education" (Kennedy et al., 2013), we already had great experiences in the past using a single (postgraduate rather than postdoctoral) research assistant to be in charge of data collection and management, and we were happy to see that this approach was successful in larger, more complex projects as well.

For more details on the lessons learned from the design phase of this study, in terms of the nuts-and-bolts of building a scenario, we refer the reader to the user manual of the Volcanic Hazard Simulation and Communicate the Quake, which will be available online in the near future.

8.3 Future Work

As the project is coming to an end, we are looking at ways to intensify our outreach, in particular to the professional hazard and disaster management community. At the time of writing, several initiatives are under way to achieve this goal. In terms of future research work, this report has only shown a selection of the data that pertained to the research questions we addressed. We collected more data to be able to answer additional research questions that are beyond the scope of this project. In the next years we anticipate conducting more analyses of these data. This will further inform the field about the possibilities, merits and drawbacks of using scenario-based role-plays as an integral (capstone) part of the curriculum, and its effects on (performance) outcomes for learners. For example, we will investigate how content knowledge (the fourth dimension in our communication model in Figure 3 and Appendix 6) is related to the other communication factors, and how student observed behaviours of communication performance (from video data and pre-post communication interviews; Appendix 7) is related to their own perceptions and confidence.

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Appendix 1A: Student and Instructor Debrief Questions

Student Questions

1. How do you expect Greymouth to be doing three months after the quake?
2. Recommendations to the Government on ways to reduce risk and improve NZ's response to and preparedness for earthquakes.
3. What are the important things that you have learned from today's activity?
4. Is there anything you would want more information on (so that you could do your role better)?
5. What topics or aspects did you find difficult to communicate?
6. What would you do differently? (Individually, and as a team)
7. What advice would you give to next year's students about the simulation?
8. Any other comments about the simulation, and your role?

Instructor Questions

Realism

- Overall, describe the students' roles and the team's role.
- Did the roles seem realistic? Why or why not?

Learning

- Did the students appear to be knowledgeable about the topics they discussed?
- Were there areas that they could be more prepared for in terms of their level of knowledge?
- Is there anything that they did today (individually, or as a team) that you would do differently?

Communication

- Did the students appear to be effective in their communication skills? In what ways were they effective?
- Were there areas that they could improve on as communicators? Explain.

Suggested Improvements

- How could the role-play be improved?
- What would you keep the same?
- What would you change?

Memorable Events

- For you, what were the memorable events of the day?

Feedback

- Do you have any other additional comments or feedback?

Appendix 1B: Student Debriefs – Feedback

It0 General (n=12), 2 Teams	**It1 Tectonics (n=10), 1 Team**	**It2 Hazards (n=2), 2 Teams**	**It3 Engineering (n=6), 1 Team**
Question: What are the important things that you have learned from today's activity?			
Teamwork (4†), Emergency response (5), Earthquake preparedness (1), Professionalism during disaster (2), How to make a map (1)	Disaster relief must be quick (1), Emergency response (2), Identify risks before an event happens (1), Teamwork (1)	Team dynamics (1), To think on my feet (1)	Emergency response (2), Social impacts of disasters (2), Teamwork (2), Working under pressure (1), Decision-making is better when information is available (1), Data isn't always available when you need it (1), The bigger picture of these events (1), Prioritization of tasks (1), Importance of critical infrastructure and resources (1), Science advisory roles (1)
Question: Is there anything you would want more information on so that you could do your role better?			
Structural engineering information (2), Role information (2), Building properties (1), Infographics (1), General earthquake research (1), Instructions (1), More time to prepare (1)	No (6), Case studies of risk assessments (1), Social effects of earthquakes (1), Interacting with the general public (1), More resources in Greymouth (1)	Broader description of the roles (1), More information about the roles (1)	No (2), Google maps files (2), More information about Greymouth (2), Hear from the real SAG (1), Weather information (1), Information on the hospital and port (1), Know the people and their resources (1), Timing of tasks could be improved (1)
Question: What would you do differently? (Individually, and as a team)			
Team communication (5), Inter-team communication (4), Do the readings (3), Focus more on roles/responsibilities (2), Better delegation (1), Better advice to the other team (1), Highlight earthquake uncertainty more (1), Be more professional (1), Better leadership skills (1)	Pre-readings in more depth (2), Communicate with other team members more (2), Be more efficient (1), Teamwork (1), Make a list of key infrastructure (1), Background knowledge of Greymouth (1)	Better integration between the teams (1), Inter-team communication (1), More professional (1), Stayed calm (1), Better teamwork (1)	Delegate tasks (2), Create a structure to the documents before writing them (1), Separating out the tasks into logical categories (1), Task delegation (1), Improve inter-team communication (1), Get familiar with Greymouth (1), Be more prepared (1), Improve team dynamics (1), Get into my role better (1)

Negative Feedback:			
We should visit the Greymouth area (2), Want to go into more detail (1), Need extended time (1), Wasn't sure my role was as important (1)	Google Docs made it hard to be concise (2), Have data logs like previous sims (1), Not use Google Docs for group editing (1), Have a role whose job it is to digest all the team's information (1)	Some of the roles could be combined (1), More time to prepare (1)	Technical set-up should be more efficient (2), Have mixed academic background exercise (1), Seat people working together (1), File sharing was hard to get used to (1)
Positive Feedback:			
Enjoyed the exercise (5), Helped me decide I want to be an engineer (1), Exercise was well organised (1), Learned a lot about earthquakes (1), Feel better prepared for earthquakes (1), Learned important skills (1), Good to be outside of my comfort zone (1),	Enjoyed the exercise (3), Excellent teaching tool (2), Exercise was organised (1), Wish we had more learning experiences like this (1), My role gave me a different perspective (1)	Exercise was enjoyable (1), Consider these roles as future jobs (1), Appreciated work of both teams (1)	Enjoyed the exercise (4), Valuable experience (1), File sharing was good for sharing information (1)
Question: What advice would you give to next year's students about the simulation?			
Take the exercise seriously (3), Do the background reading (3), Focus on communication (2), Focus on your role (2), Work together (2), Know your role and other's roles (2), Become familiar with Greymouth (2), Think of the bigger picture (1), Think about the ramifications of what you say (1), Read about emergency response (1), Be efficient (1)	Work together (3), Do the background reading (2), Be open (2), Communicate with your team (2), Be efficient (1), Have fun with the experience (1), Know your roles and other's roles (1), Stick to the basics (1),	Know your role (3), Stick to your role (1), Use the resources and facilitators (1), Don't take it too seriously (1), Delegate tasks (1), Help your team mates (1), Keep your team leader informed (1)	Organise the team (1), Delegate tasks (1), Assign people to speak in given tasks (1), Use the whiteboard more (1), Use top-down team structure (1), Imagine you are in Greymouth (1), Get to know the local area (1), It can be frustrating (1), Get into the scenario (1)

†Questions were open-ended, which allowed for multiple items. Therefore frequencies represented here do not represent individual student responses

Appendix 1C: Instructor Debriefs – Feedback

	It0 (n=2) (Emailed open-ended survey)	**it4 (n=4) (Focus group)**
Facilitator(s) expertise	Hazards researcher (1), Emergency manager (1)	Hazards researcher (1), Landslide researcher (1), Student exchange coordinator (1), Education researcher (1)
Was the exercise realistic? Why or why not?	**Yes, realistic (2).** Very real (1), Students had individual roles and responsibilities (1), Physical separation (two rooms) was real (1), They focused on their roles (1), Students had to initiate intra-team communication (1), Team structure that resembled real-life response chains (1), Students adhered to structure (1), Communication was a bit disorganised (1)	**Yes, realistic (4).** Realistic teams to separate into (1), One team did the science and the other team did the decision-making (1), Would be beneficial if students knew more science/geology (2)
Were the students effective in their communication skills?	***Not asked in this version***	**Yes (4).** Effective communicating with the public (1), Students were impressive (1), Students spoke with confidence (1)
Negatives feedback and suggested improvements	Up the pace (1), Throw in 'curve-balls' (1), Students could have more guidance on infographics (1), Give CDEM SOPs, to save them time (1), Give them more time to consider their decisions (1), Students could benefit from more reflection during the exercise (1), Students could use more challenges at the end (1)	Students should prepare more for their roles (1), Students should do the readings (1), Could have used the facilitators more (1), Students could use guidance on the infographic task (2), Science ethics task was confusing for students (1), Students were not familiar with the format of communication events (e.g., Panel Discussion) (1)
Positive comments	Awesome exercise (1)	Students did well with the New Zealand-based information (1), CDEM Team was very impressive (1), Wouldn't change a thing about it (1), Great exercise (1), Very happy with it (1), Interface worked really well (1), The students' engagement was really great (1), The students seemed confident (1), File sharing was really good (1)
Memorable moments from the day	Panel discussion (1), Watching students' skills and knowledge increase through the exercise (1)	Twitter and hashtags (Panel Discussion task) (1)

Quotes	‘At the end of the day “wrap-up”, the scientists were much more confident, organised, articulate, and prepared than at meetings called earlier in the exercise. They displayed a significant increase in knowledge and progress in their performance and strength as a team.’ (Hazards researcher), ‘[Students] were very quick to understand and adopt. Most of them, as individuals, were on a steep learning curve through the first parts of the exercise, but they were extremely open and receptive and their skill level was increasing dramatically (e.g., decision-making, presentation)’ (Emergency manager)	‘Whether [the students] were experts or not, they talked with confidence. And that's something you have to express to the public.’ (Landslide researcher), ‘I think [the students] could've been more prepared in terms of their specific roles, because I think that they had a pretty extensive bibliography. And I'm not really sure how many people actually read them.’ (Education researcher), ‘I thought that the way that they interacted, was just, like a great group. The engagement was really great, and people were asking questions, and they worked really fluidly’ (Landslide researcher)

	It5 (n=4) (Emailed, open-ended survey)	**it6 (n=1) (Emailed, open-ended survey)**
Facilitator(s) expertise	Psychology researcher (1), Hazards researcher (2), Social science researcher (1)	Geographer (1)
Was the exercise realistic? Why or why not?	Realistic (1), Not realistic (1), Not authentic (1), Exercise did not conform to CIMS (1)	Exercise ‘got pretty close’ (1), Students recognised their roles and responsibilities (1), Students maintained the team structure (1), Tasks were shared a lot more than they would be in the real world (1)
Were the students effective in their communication skills?	Some were ‘fair’ (1), They used ‘key points’ (1), They oriented their message towards providing advice which aids in decision-making (1), Included a message saying that ‘aftershocks are expected’ (1), Some of their statements were clear and concise (1) Communication was not good between groups (1), Communication was good within groups (1), Some language was inflammatory (1)	Students were very good at identifying and including the relevant information (1), They were too technical, they should simplify it (1), They should focus on the audience (1)
Negative feedback and suggested improvements	Participants couldn't use the technology (1), Large group, so few participants communicated in public speaking (1), Make all participants part of the Public Information group (1), Include general information about Greymouth (1), Replicate CIMS structure (1), Have one of the participants as the Mayor, to allow them to communicate (1), Have two screens (one to show file sharing and the other to show the exercise PowerPoint) (1), More information	Some students didn’t rise to the challenge (1), Tasks to further build rapport within the group would help (1), We should further encourage the students to ask questions of the presenters (1)

	for participants is needed (aims and instructions to the exercise) (2), Show participants why exercises are good for their career (1)	
Positive comments	Exercise went well (1), PowerPoint interface was excellent, clear and easy to use (1), Use of Google Drive was useful and good for participants to use in their careers (1), Tasks were varied and effective (1), I enjoyed being a part of the exercise (1), Great for tips on facilitating (1)	Exercise worked well (1)
Memorable moments from the day	First time observing an exercise (1), Not answered (2), Press conference (1), Working with the science group on what they should communicate (1)	The [public speaking] presentations (1)
Quotes	'The memorable events for me were the press conference ... seeing some of the participants really get into their roles ... and working with the participants playing the role of scientists, and helping them identify what information a scientist might want to communicate.' (Social science researcher), 'Participants who were knowledgeable discussed topics and took leadership roles in the team. Participants who were less comfortable in roles took more supportive roles within the teams.' (Hazards researcher), 'There was a lot of discussion focused on the event that had happened but not much conversation about the future situation, for example, future aftershocks and continued disruptions, etcetera' (Hazards researcher)	'I feel the students did start to recognise their roles and responsibilities as the exercises progressed', 'The students were very good at identifying and including the relevant information, although erred on the side of being too technical. Simplifying and really identifying and focussing on the audience would have benefitted the group.'

Appendix 1D: Student Debriefs – Communication

<table>
<tr><td colspan="2">Question: What are the important things that you have learned from today's activity? (RE: Communication)</td></tr>
<tr><td><u>COMMUNICATION</u> (45):, Difficulty/delicacy of communication (6), Communication is important (6), Careful use of language and jargon (4), Information needs and communication with different stakeholders (3), Prioritising and filtering of information (3), Presentation skills (2), Strategies to use when responding to tough questions (2), Knowing the audience (2), Practiscing communication helps you to become a better communicator (1), Prepare your communication (1), Target what you say to your audience (1), Maps are essential for decision making and communication (1), Translating information into actions (1),. The public may not listen to you and your advice (1).</td><td>Student Quotes: 'I learned the importance of verbal communication to the public ... [including] the wording and attitude that you display.' (Gen version, it0), 'Know your audience, and tailor your content to what they need to know.' (Tect vers, it1), 'It is always difficult to get enough and the right information across accurately. Need to be very careful in the language, etcetera, used. Practice doing this helps." (Tect vers, it1), 'You get so caught up in little details and sometimes miss the big picture with respect to what it means for the general public or how it could be communicated to them.' (Eng vers, it3)</td></tr>
<tr><td colspan="2">Question: What topics or aspects did you find difficult to communicate?</td></tr>
<tr><td><u>CONTENT</u> (22): Pure science and geology aspects (5), Earthquake risk (4), Uncertainty (4), Future earthquake events and recurrence (3), Not pure science and non-technical aspects (2), What to expect after an earthquake (1), Quantification of risk (1), Detailed information about local damage (1), Seismicity (1).
<u>COMMUNICATION STRATEGIES</u> (18): Reduce technical language and jargon (5), Avoiding panic and confusion (2), The level of detail to communicate (2), Communicating with insufficient information (2), Communicating under pressure (1), Simplifying complex information (1), Making the science relevant (1), Knowing the audience (1), Using emotions appropriately (1), Using understandable terminology (1), Coping with the large amount of information (1).
<u>AUDIENCE/STAKEHOLDERS</u> (13): To the Public (8), With or to the other team (3), To the team leader (1), Anticipating what the public thinks (1).</td><td>Student Quotes: 'I found it difficult to communicate about risk. Because we couldn't state definite things, like when exactly the earthquake was going to occur, it was hard to inform the public.' (Gen version, it0), 'It was a challenge to communicate the hazard and risk of seismic events in a way that was relevant, informative, and understandable for the community while not creating panic or confusion.' (Tect vers, it1), 'Finding the balance between showing some compassion and showing the cold hard facts was difficult at times.' (Eng vers, it3), 'There is a fine balance between being too detailed and jargon-y and not providing enough detail.' (Eng vers, it3)</td></tr>
<tr><td colspan="2">Question: What would you do differently? (Individually, and as a team RE: Communication)</td></tr>
<tr><td>Focus on communication (2), Be prepared for communication tasks (1), Be precise (1), Be concise (1), Keep it simple (1), Avoid jargon (1), Use analogies and metaphors (1), Put yourself in the audience's shoes (1), Don't be afraid to do public speaking (1), Think about how to relate your research to the public (1), Think about the ramifications of what you say (1), Communicate in more depth (1), Establish communication protocols (1)</td><td>Student Quotes: 'Keep your communication simple with no fluff, often the excessive details are unnecessary and distract from the overall purpose of the task.' (Tect vers, it1), 'Don't be afraid to get up and speak' (Tect vers, it1), 'Keep it simple, just stick to the basics and explain them very clearly.' (Tect vers, It1)</td></tr>
</table>

Appendix 2: Communication Experiences Questionnaire

Section A.
Below are a set of statements about possible communication experiences that you have had and the audiences to which you communicated. Please indicate the ***number of experiences*** you have had with each of these items and contexts (oral presentations, posters, debate, speech, performing arts, scientific teaching, and group discussions). ***Include all of the experiences from your high school, university education and work experience.***

People's experiences in communication vary from person to person. It is OK to report 'no experience'.

ORAL PRESENTATIONS:	**No experience**	**Few experiences**	**Some experience**	**Many experiences**	**Numerous experiences**
1. In the **classroom**, in front of your peers and instructor(s), as an assignment.	0 experiences	1 to 9 experiences	10 to 15 experiences	16 to 20 experiences	More than 20 experiences
2. At a **professional scientific conference** or symposium, requiring acceptance of an abstract.	0 experiences	1 to 5 experiences	6 to 10 experiences	11 to 20 experiences	More than 20 experiences
3. In your **university department** as a formal seminar, in front of your peers and superiors.	0 experiences	1 to 5 experiences	6 to 10 experiences	11 to 20 experiences	More than 20 experiences
4. In your **workplace**, in front of your colleagues and superiors.	0 experiences	1 to 9 experiences	10 to 15 experiences	16 to 20 experiences	More than 20 experiences

POSTERS:	**No experience**	**Few experiences**	**Some experience**	**Many experiences**	**Numerous experiences**
5. In the **classroom**, in front of your peers and instructor(s), as an assignment.	0 experiences	1 to 3 experiences	4 to 6 experiences	7 to 10 experiences	More than 10 experiences
6. At a **professional scientific conference** or symposium, requiring acceptance of an abstract.	0 experiences	1 to 3 experiences	4 to 6 experiences	7 to 10 experiences	More than 10 experiences

DEBATE:	**No experience**	**Few experiences**	**Some experience**	**Many experiences**	**Numerous experiences**
7. Formal **debate**, where you justify a position, present arguments and respond to questions.	0 experiences	1 to 10 experiences	11 to 20 experiences	21 to 30 experiences	More than 30 experiences

SPEECH:	**No experience**	**Few experiences**	**Some experience**	**Many experiences**	**Numerous experiences**
8. Presented a scripted **speech** in front of an audience. Topics may be general or scientific.	0 experiences	1 to 10 experiences	11 to 20 experiences	21 to 30 experiences	More than 30 experiences

PERFORMING ARTS:	**No experience**	**Few experiences**	**Some experience**	**Many experiences**	**Numerous experiences**
9. Performed an **artistic piece** in front of an audience (e.g., theatre, music, dance).	0 experiences	1 to 10 experiences	11 to 20 experiences	21 to 30 experiences	More than 30 experiences

TEACHING OTHERS ABOUT A SCIENTIFIC TOPIC(S) YOU ARE KNOWLEDGEABLE ABOUT:	**No experience**	**Few experiences**	**Some experience**	**Many experiences**	**Numerous experiences**
10. To **students** (e.g., in the classroom, lab, or field environments).	0 experiences	1 to 15 experiences	16 to 30 experiences	31 to 50 experiences	More than 50 experiences
11. To **non-specialist people**, in a formal setting (e.g., general public, local interest groups, museum attendees).	0 experiences	1 to 10 experiences	11 to 20 experiences	21 to 30 experiences	More than 30 experiences

GROUP DISCUSSION/MEETING:	**No experience**	**Few experiences**	**Some experience**	**Many experiences**	**Numerous experiences**
12. Shared your **opinions/ideas** within a group discussion.	0 experiences	1 to 15 experiences	16 to 30 experiences	31 to 50 experiences	More than 50 experiences
13. **Led a group discussion** on a topic or project.	0 experiences	1 to 10 experiences	11 to 20 experiences	21 to 30 experiences	More than 30 experiences
14. Shared your **opinions/ideas** at a meeting with your **superior/manager** (e.g. research group, thesis meeting, staff meeting).	0 experiences	1 to 10 experiences	11 to 20 experiences	21 to 30 experiences	More than 30 experiences

Section B.

List and describe any additional **oral communication experience(s)** you've had, not mentioned above, which you feel have improved your communication skills:

Section C.
Below are a set of statements describing possible communication experiences. Please indicate in the appropriate box **if you have ever** provided feedback, received feedback or evaluated yourself regarding these communication experiences.

	Oral Presentatio n	**Poster**	**Debate**	**Speech**	**Performin g Arts**	**Teachin g**	**Group Discussio n**
1. Have you ever **received feedback** on this type of communication experience?	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
2. Have you ever **provided feedback** on this type of communication experience?	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
3. Have you ever **evaluated yourself** on this type of communication experience?	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**

Appendix 3: Perceptions of Crisis Communication Questionnaire

Section 1: Communicating with the Public

Scenario:
You are a **geoscientist**. There has been a large, devastating earthquake. You are mandated by your organisation to **communicate about your science** effectively within the first 72 hours after the event in a **press conference** format, to differing target audiences who are impacted by this situation. In particular, think about how **appropriate** different aspects of communication are when communicating with the ***public***.

Please circle the answer that best describes your agreement with the following statements (strongly disagree, disagree, neutral, agree or strongly agree). If you would like to comment on, or explain any of your responses to the questions, please write in the Section 1 Comments on the following page.

'In an earthquake crisis, scientific information and its presentation to the PUBLIC should ...'

1. '... help people understand **why** the earthquake has occurred.'	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
2. '... be **comprehensive** (i.e., include all scientific aspects discussed behind the scenes).'	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
3. '... not show the scientist's **emotions**.'	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
4. '... be **targeted** to particular audiences.'	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
5. '... be clear about the communications' **purpose**.'	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
6. '... reflect audience **diversity**.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
7. '... be in the form of a **dialogue** (two-way communication).'	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

8. '... acknowledge **political influence or agenda** on the communication.'	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
9. '... explain the **errors** and **uncertainties** with the data analyses.'	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
10. '... allow the scientist to show **enthusiasm** for the scientific or engineering concepts they are discussing.'	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
11. '... be **transparent** about how the data are being interpreted.'	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

'In an earthquake crisis, scientific information and its presentation to the PUBLIC should ...'

12. '... **provide advice**.'	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
13. '... **empower** people to take **action**.'	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
14. '... contain **greetings** and **customs** specific to particular audiences.'	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
15. '... be used to **build trust** between the scientists and the community.'	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
16. '… acknowledge that the interpretations have the **potential to change**.'	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
17. '... not include information relating to **past crisis**	Strongly	Disagree	Neutral	Agree	Strongly

scenarios.’	Disagree				Agree
18. ‘... increase awareness of **what** is occurring.’	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
19. ‘... avoid describing a **worst case scenario**.’	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
20. ‘... only include the **most important** data.’	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
21. ‘... avoid **appearing casual** about the situation.’	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
22. ‘... not acknowledge **sensitive** or **controversial** topics.’	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
23. ‘… acknowledge that the scientists’ understanding of the data is based on **what is available at that time**.’	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
24. ‘... reflect that the scientist is **confident** in their area of expertise.’	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
25. ‘... provide an **estimated time frame** for the duration of the crisis.’	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
26. ‘... **persuade** people to **care**.’	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Comments

(If you would like to comment on your responses to ***Section 1,*** please do so below.)

Question number	Comments:

Section 2: Types of Media Used to Communicate

Which of the following means of conveying information (i.e., media) to the **public** are appropriate to use **during an earthquake crisis**? Please **circle** the answer that **best** describes your agreement (strongly disagree, disagree, neutral, agree or strongly agree).

When communicating with **the PUBLIC**, it is **appropriate** to use...

Press conferences	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Radio bulletins or statements	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Media interviews	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Websites	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Social media (e.g., Facebook, Twitter)	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Town hall and community meetings	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Section 3: Language, Numbers and Visuals in Communication

The following statements describe possible components of communication with varying target audiences. Please **circle** the answer that **best** describes your agreement (strongly disagree, disagree, neutral, agree, or strongly agree). Note: **Emergency management professionals** are those that are responsible for making decisions during a crisis.

1. When communicating with **GEOSCIENTISTS**, it is **appropriate** to use:

Scientific terminology	**Everyday language**	**Formal language**	**Analogies**[1]	**Metaphors**[2]	**Indigenous knowledge**
☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree	☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree	☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree	☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree	☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree	☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

2. When communicating with **EMERGENCY MANAGEMENT PROFESSIONALS**, it is **appropriate** to use:

Scientific terminology	**Everyday language**	**Formal language**	**Analogies**[1]	**Metaphors**[2]	**Indigenous knowledge**
☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree	☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree	☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree	☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree	☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree	☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

3. When communicating with the **PUBLIC**, it is **appropriate** to use:

Scientific terminology	**Everyday language**	**Formal language**	**Analogies**[1]	**Metaphors**[2]	**Indigenous knowledge**
☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree	☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree	☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree	☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree	☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree	☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

[1] An **analogy** explicitly compares two situations, people or objects. *For example: 'The layers of rock in the ground are **like the layers of a cake**. Each layer is made of different materials, and has different properties.'*

[2] A **metaphor** is a word or phrase that ordinarily designates one thing but is used to designate another, thus making an implicit or hidden comparison. Metaphors are not taken literally. *For example: 'Atmospheric gasses form a **blanket** around the earth.'*

4. When communicating with **GEOSCIENTISTS**, it is **appropriate** to use:

Numbers	**Probabilities in odds (e.g., 1 in 5)**	**Probabilities in percentages (e.g., 20%)**	**Statistics**
☐ Strongly Disagree	☐ Strongly Disagree	☐ Strongly Disagree	☐ Strongly Disagree
☐ Disagree	☐ Disagree	☐ Disagree	☐ Disagree
☐ Neutral	☐ Neutral	☐ Neutral	☐ Neutral
☐ Agree	☐ Agree	☐ Agree	☐ Agree
☐ Strongly Agree	☐ Strongly Agree	☐ Strongly Agree	☐ Strongly Agree

5. When communicating with **EMERGENCY MANAGEMENT PROFESSIONALS**, it is **appropriate** to use:

Numbers	**Probabilities in odds (e.g., 1 in 5)**	**Probabilities in percentages (e.g., 20%)**	**Statistics**
☐ Strongly Disagree	☐ Strongly Disagree	☐ Strongly Disagree	☐ Strongly Disagree
☐ Disagree	☐ Disagree	☐ Disagree	☐ Disagree
☐ Neutral	☐ Neutral	☐ Neutral	☐ Neutral
☐ Agree	☐ Agree	☐ Agree	☐ Agree
☐ Strongly Agree	☐ Strongly Agree	☐ Strongly Agree	☐ Strongly Agree

6. When communicating with the **PUBLIC**, it is **appropriate** to use:

Numbers	**Probabilities in odds (e.g., 1 in 5)**	**Probabilities in percentages (e.g., 20%)**	**Statistics**
☐ Strongly Disagree	☐ Strongly Disagree	☐ Strongly Disagree	☐ Strongly Disagree
☐ Disagree	☐ Disagree	☐ Disagree	☐ Disagree
☐ Neutral	☐ Neutral	☐ Neutral	☐ Neutral
☐ Agree	☐ Agree	☐ Agree	☐ Agree
☐ Strongly Agree	☐ Strongly Agree	☐ Strongly Agree	☐ Strongly Agree

7. When communicating with **GEOSCIENTISTS**, it is **appropriate** to use:

Audiovisuals (images and videos)	**Maps**	**Graphs and plots**
☐ Strongly Disagree	☐ Strongly Disagree	☐ Strongly Disagree
☐ Disagree	☐ Disagree	☐ Disagree
☐ Neutral	☐ Neutral	☐ Neutral
☐ Agree	☐ Agree	☐ Agree
☐ Strongly Agree	☐ Strongly Agree	☐ Strongly Agree

8. When communicating with **EMERGENCY MANAGEMENT PROFESSIONALS**, it is **appropriate** to use:

Audiovisuals (images and videos)	**Maps**	**Graphs and plots**
☐ Strongly Disagree	☐ Strongly Disagree	☐ Strongly Disagree
☐ Disagree	☐ Disagree	☐ Disagree
☐ Neutral	☐ Neutral	☐ Neutral
☐ Agree	☐ Agree	☐ Agree
☐ Strongly Agree	☐ Strongly Agree	☐ Strongly Agree

9. When communicating with the **PUBLIC**, it is **appropriate** to use:

Audiovisuals (images and videos)	Maps	Graphs and plots
☐ Strongly Disagree	☐ Strongly Disagree	☐ Strongly Disagree
☐ Disagree	☐ Disagree	☐ Disagree
☐ Neutral	☐ Neutral	☐ Neutral
☐ Agree	☐ Agree	☐ Agree
☐ Strongly Agree	☐ Strongly Agree	☐ Strongly Agree

Section 4: Significance of Communication

Please **circle** the answer that **best** describes your agreement with the following statements.

1. 'Part of being a scientist is being an **effective** communicator.'	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
2. 'To be an effective communicator, you need to **practise** your communication skills.'	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
3. 'As a scientist, you should be **accountable** for the scientific advice that you provide.'	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
4. 'As a scientist, you should be **liable** for the scientific advice that you provide.'	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Comments:

Section 5: Open-ended Question

What does **science communication** mean to you? Please explain.

Appendix 4: Expert Perceptions of Crisis Communication

Communicating with the Public

Scenario: *You are a geoscientist. There has been a large, devastating earthquake. You are mandated by your organisation to communicate about your science effectively within the first 72 hours after the event in a press conference format, to differing target audiences who are impacted by this situation. In particular, think about how appropriate different aspects of communication are when communicating with the public.*

Section 1: Communication Strategies

In an earthquake crisis, scientific information and its presentation to the public should:	Median	Mean	A	N	D
1. Help people understand why the earthquake has occurred (Agree)	4	4.09	39	3	2
2. Be comprehensive (i.e., include all scientific aspects discussed behind the scenes) (Disagree)	*2*	*2.64*	*10*	*10*	*24*
3. Not show the scientist's emotions (Disagree)	*2*	*2.70*	*10*	*11*	*23*
4. Be targeted to particular audiences (Agree)	4	3.91	35	3	6
5. Be clear about the communication's purpose (Strongly Agree)	5	4.53	42	1	0
6. Reflect audience diversity (Agree)	4	4.19	37	5	0
7. Be in the form of a dialogue (two-way communication) (Agree)	4	3.81	29	11	3
8. Acknowledge political influence/agenda on the communication (Neutral/Agree)	*3*	*3.16*	*18*	*13*	*12*
9. Explain the errors and uncertainties with the data analyses (Agree)	4	4.09	35	6	2
10. Allow the scientist to show enthusiasm for the scientific/engineering concepts they are discussing (Agree)	4	3.75	31	7	6
11. Be transparent about how the data are being interpreted (Agree)	4	4.32	39	5	0
12. Provide advice (Agree)	4	3.66	30	8	6
13. Empower people to take action (Agree)	4	4.09	37	5	2
14. Contain greetings and customs specific to particular audiences (Agree)	*3.5*	*3.50*	*22*	*19*	*3*
15. Be used to build trust between the scientists and the community (Strongly Agree)	5	4.64	42	1	1
16. Acknowledge that the interpretations have the potential to change (Strongly Agree)	5	4.59	43	1	0
17. Not include information relating to past crisis scenarios (Disagree)	2	2.39	5	10	29
18. Increase awareness of what is occurring (Agree)	4	4.45	44	0	0

19. Avoid describing a worst case scenario (Disagree)	2	2.45	5	12	27
20. Only include the most important data (Neutral/Agree)	*3*	*3.34*	*21*	*14*	*9*
21. Avoid appearing casual about the situation (Agree)	4	4.07	36	5	3
22. Not acknowledge sensitive or controversial topics (Disagree)	2	2.02	2	5	37
23. Acknowledge that the scientists' understanding of the data is based on what is available at that time (Strongly Agree)	5	4.66	43	1	0
24. Reflect that the scientist is confident in their area of expertise (Agree)	4	4.09	38	6	0
25. Provide an estimated time frame for the duration of the crisis (Agree)	*4*	*3.53*	*24*	*16*	*3*
26. Persuade people to care (Neutral/Agree)	*3*	*3.44*	*17*	*23*	*3*

Section 2: Media

When communicating with the public, it is appropriate to use:	Median	Mean	A	N	D
27. Press conferences (Agree)	4	4.36	41	3	0
28. Radio bulletins or statements (Agree)	4	4.48	44	0	0
29. Media interviews (Strongly Agree)	5	4.57	44	0	0
30. Websites (Strongly Agree)	5	4.57	44	0	0
31. Social media (e.g., Facebook, Twitter) (Agree)	4	4.36	42	2	0
32. Townhall and community meetings (Strongly Agree)	5	4.43	41	2	1

Section 3: Language, Numbers and Visuals

When communicating with the public, it is appropriate to use:	Median	Mean	A	N	D
33. Scientific terminology (Neutral/Agree)	*3*	*3.07*	*18*	*10*	*15*
34. Everyday language (Strongly Agree)	4.5	4.48	43	1	0
35. Formal language (Neutral/Agree)	*3*	*3.21*	*19*	*13*	*11*
36. Analogies (Agree)	4	4.30	42	1	1
37. Metaphors (Agree)	4	3.74	32	3	8
38. Indigenous knowledge (Agree)	4	3.88	33	8	2
39. Numbers (Agree)	4	4.00	36	6	1
40. Probabilities in odds (e.g., 1 in 5) (Agree)	4	3.91	36	4	4
41. Probabilities in percentages (e.g., 20%) (Agree)	4	3.72	29	10	4

42. Statistics (Neutral/Agree)	*3*	*3.19*	*18*	*15*	*10*
43. Audiovisuals (images and videos) (Strongly Agree)	5	4.721	42	1	0
44. Maps (Strongly Agree)	5	4.488	42	1	0
45. Graphs and plots (Neutral/Agree)	*3*	*3.442*	*20*	*16*	*7*

Other Stakeholders:

When communicating with other geoscientists it is appropriate to use:	**Median**	**Mean**	**A**	**N**	**D**
33. Scientific terminology (Agree)	4.5	4.34	40	1	3
34. Everyday language (Agree)	4	4.07	34	10	0
35. Formal language (Neutral/Agree)	3	3.34	17	20	7
36. Analogies (Agree)	4	3.75	29	12	3
37. Metaphors (Neutral/Agree)	3	3.20	17	15	12
38. Indigenous knowledge (Agree)	4	3.48	23	17	4
39. Numbers (Strongly Agree)	5	4.56	42	0	1
40. Probabilities in odds (e.g., 1 in 5) (Agree)	4	4.21	37	5	1
41. Probabilities in percentages (e.g., 20%) (Strongly Agree)	5	4.33	37	4	2
42. Statistics (Agree)	4	4.44	42	0	1
43. Audiovisuals (images and videos) (Agree)	4	4.333	38	3	1
44. Maps (Strongly Agree)	5	4.667	42	0	0
45. Graphs and plots (Neutral/Agree)	5	4.643	42	0	0

When communicating with emergency managers it is appropriate to use:	**Median**	**Mean**	**A**	**N**	**D**
33. Scientific terminology (Agree)	4	3.63	28	10	5
34. Everyday language (Agree)	4	4.35	41	2	0
35. Formal language (Agree)	4	3.65	27	11	5
36. Analogies (Agree)	4	4.05	39	2	2
37. Metaphors (Agree)	4	3.56	27	7	9
38. Indigenous knowledge (Agree)	4	3.70	30	10	3
39. Numbers (Agree)	4	4.16	40	2	1

40. Probabilities in odds (e.g., 1 in 5) (Agree)	4	4.23	41	1	1
41. Probabilities in percentages (e.g., 20%) (Agree)	4	4.05	36	5	2
42. Statistics (Agree)	4	3.79	28	12	3
43. Audiovisuals (images and videos) (Strongly Agree)	5	4.524	40	2	0
44. Maps (Strongly Agree)	5	4.571	42	0	0
45. Graphs and plots (Agree)	4	4.071	34	7	1

Section 4: Significance of Communication

	Median	**Mean**	**A**	**N**	**D**
46. Part of being a scientist is being an effective communicator (Strongly Agree)	5	4.36	37	5	2
47. To be an effective communicator, you need to practise your communication skills (Strongly Agree)	5	4.70	44	0	0
48. As a scientist, you should be accountable for the scientific advice that you provide (Agree)	4	4.25	39	5	0
49. As a scientist, you should be liable for the scientific advice that you provide (Neutral/Disagree)	*3*	*2.77*	*10*	*16*	*18*

Appendix 5: Study Participants' Perceptions of Crisis Communication, by Statement

	it4			it6			it5	
Section 1: Communicating with the Public	**Pre %F**	**Post %F**	***Change***	**Pre %F**	**Post %F**	***Change***	**Post %F**	**Descriptions and Statistical Tests**
1. Help people understand why the earthquake has occurred (Agree)	87	93	*7*	80	100	*20*	33*	It5 (EM professionals) had significantly lower scores than students (H (chi^2)=9.43, p=0.003).
2. Be comprehensive (i.e., include all scientific aspects discussed behind the scenes) (Disagree)	47	33	*-13*	80	70	*-10*	56	All groups had different post-scores (different medians), and it4 and it6 showed negative change. Tests were not significant.
3. Not show the scientist's emotions (Disagree)	33	87	*54†*	20	30*	*10*	56	It4 and it6 had low pre-scores (H (chi^2): 8.075; p=0.00953). Significant, positive changes for it4 (z=3.1685, p=0.0015), and positive changes for it6 (not significant).
4. Be targeted to particular audiences (Agree)	53	80	*27*	70	80	*10*	89	All groups showed high post-scores, and it4 and it6 showed positive changes, though they were not significant.
5. Be clear about the communication's purpose (Strongly Agree)	87	93	*7*	100	100	*0*	100	All groups had positive pre- and post-scores, with small positive change by it4 students (not significant).
6. Reflect audience diversity (Agree)	87	93	*7*	70	80	*10*	100	All groups had positive pre- and post-scores, with small positive changes for it4 and it6 (not significant).
7. Be in the form of a dialogue (two-way communication) (Agree)	47	67	*20†*	30	40	*10*	56	It4 and it6 had low pres, but both groups showed positive changes (it4 change was significant). All group post-scores are within the medium scores.
8. Acknowledge political influence/agenda on the communication (Neutral/Agree)	40	33	*-7*	30	10	*-20*	33	All groups had low scores (pre and post), with both student groups showing negative changes (though not significant).
9. Explain the errors and uncertainties with the data analyses (Agree)	64	87*	*22†*	70	90	*20*	56	All groups had medium-high post-scores but it4 had a higher median (H(chi^2)=5.846, p=0.03357), and both student groups had positive changes, it4 changes were significant (z=3.2757, p=0.00105), while it6 were not.

10. Allow the scientist to show enthusiasm for the scientific/engineering concepts they are discussing (Agree)	40	73	*33†*	50	70	*20*	56	Both it4 and it6 groups had achieved positive changes. It4 changes were significant (z=2.1264, p=0.03347) and it6 changes were not. It5 had lower post-scores, but the difference was not significant.
11. Be transparent about how the data are being interpreted (Agree)	80	93	*13†*	80	90	*10*	78	Most scores were high, with positive changes recorded for both it4 (significant change, z=2.2645, p=0.02354) and it6 (not significant).
12. Provide advice (Agree)	87	87	*0*	60	80	*20*	78	All groups showed high post-scores, with it6 having a positive change (though not significant).
13. Empower people to take action (Agree)	80	93	*13*	50	70	*20*	100	All groups showed high post-scores, with it4 and it6 showing positive changes (though not significant).
14. Contain greetings and customs specific to particular audiences (Agree)	67	67	*0*	70	50	*-20*	67	All groups showed medium to high scores, and it6 showed negative changes (but not significant).
15. Be used to build trust between the scientists and the community (Strongly Agree)	80	100	*20†*	90	90	*0*	100	All groups had high scores, it4 has a high positive change.
16. Acknowledge that the interpretations have the potential to change (Strongly Agree)	93	100	*7†*	90	100	*10*	100	All groups had high pre- and post-scores. Changes for it4 were significant (z=2.1106, p=0.03481), but for it6 were not.
17. Not include information relating to past crisis scenarios (Disagree)	60	60	*0*	80	70	*-10*	22*	It6 showed a negative shift (though not significant), and it5 has much lower post-scores (H (chi2): 7.527; p=0.01352).
18. Increase awareness of what is occurring (Agree)	93	100	*7*	100	100	*0*	89	All groups had high scores, it4 had a small positive change (though not significant).
19. Avoid describing a worst case scenario (Disagree)	27	13	*-20*	0	0	*0*	33	All groups had very low scores, with it4 showing a negative shift (not significant).
20. Only include the most important data (Neutral/Agree)	47	60	*13*	80	70	*-10*	100	It4 and it6 had slightly lower scores than it5 (not significant). It4 showed positive changes, and it6 showed a negative change (though both tests were not significant).
21. Avoid appearing casual about the situation (Agree)	73	93	*20*	90	100	*10*	100	All groups showed high scores, with both groups showing positive changes (though not significant).
22. Not acknowledge	47	93	*46†*	40	40	*0*	56	All groups showed medium scores,

sensitive or controversial topics (Disagree)								and it4 achieved significant positive changes (z=2.8497, p=0.004376).
23. Acknowledge that the scientists' understanding of the data is based on what is available at that time (Strongly Agree)	100	100	*0*	90	90	*0*	100	All groups showed very high scores.
24. Reflect that the scientist is confident in their area of expertise (Agree)	93	93	*0*	90	90	*0*	100	All groups showed very high scores.
25. Provide an estimated time frame for the duration of the crisis (Agree)	80	80	*0*	70	70	*0*	44	It5 had lower post-scores than student groups (though test was not significant).
26. Persuade people to care (Neutral/Agree)	53	60	*7*	40	80	*40*	56	All groups showed medium-high scores. it6 showed large positive change (z=2.2361, p=0.025347).

Section 4: Importance of Communication	it4			it6			it5	Descriptions and Statistical Tests
	Pre %F	**Post %F**	***Change***	**Pre %F**	**Post %F**	***Change***	**Post %F**	
46. Part of being a scientist is being an effective communicator (Strongly Agree)	100	100	*0*	100	90	*-10*	71	All groups showed very high scores, but it5 had lower scores than it4 and it6 (though not significant).
47. To be an effective communicator, you need to practise your communication skills (Strongly Agree)	100	100	*0*	100	100	*0*	100	All participants had perfect scores.
48. As a scientist, you should be accountable for the scientific advice that you provide (Agree)	73	87	*13*	80	90	*10*	71	Generally high scores, with both it4 and 6 showing positive changes (though not significant).
49. As a scientist, you should be liable for the scientific advice that you provide (Neutral/Disagree)	33	40	*7*	40	60	*20*	29	Most groups had low scores, with it4 and 6 showing positive changes (though not significant).

Section 2: Media	it4			it6			it5	Descriptions and Statistical Tests
	Pre %F	**Post %F**	***Change***	**Pre %F**	**Post %F**	***Change***	**Post %F**	
27. Press conferences (Agree)	87	100	*13†*	100	100	*0*	100	All groups showed high scores, with it4 showing a significant positive change (z=2.7136, p=0.006656).

28. Radio bulletins or statements (Agree)	87	100	*13*	100	100	*0*	100	All groups showed high scores, with it4 showing a positive change (not significant).
29. Media interviews (Strongly Agree)	67	93	*27*	80	90	*10*	100	All groups had high post-scores, with it4 and it6 both improving, though tests were not significant.
30. Websites (Strongly Agree)	93	93	*0*	70	70*	*0*	100	All groups showed medium-high scores, with it6 having a significantly lower post-score (H (chi2): 8.021, p=0.005474).
31. Social media (e.g., Facebook, Twitter) (Agree)	73	100	*27†*	40	50*	*10*	100	it6 had lower post-scores than it4 and it5 (H (chi2): 12.94, p=0.0003), and both student groups showed positive changes; it4 was significant (z=2.2323, p=0.025597) and it6 was not.
32. Townhall and community meetings (Strongly Agree)	100	100	*0*	100	90	*-10*	78*	All groups had high scores, but it5 had a slightly lower post-score (H (chi2): 5.996, p=0.01966), and it6 showed a negative change, though it was not significant.

Section 3: Language, Numbers and Visuals	**it4**			**it6**			**it5**	**Descriptions and Statistical Tests**
	Pre %F	**Post %F**	***Change***	**Pre %F**	**Post %F**	***Change***	**Post %F**	
33. Scientific terminology (Neutral/Agree)	7	20	*13*	10	0	*-10*	17	All groups had low scores. It4 had a positive change, while it6 showed a negative change, but both tests were not significant.
34. Everyday language (Strongly Agree)	100	100	*0*	80	100	*20*	88	All groups had high scores, with it6 showing a positive change (not significant).
35. Formal language (Neutral/Agree)	7	20	*13*	60	60	*0*	25	Most of the scores were low, except it6 (though the difference was not significant). A positive change for it4 students was not significant.
36. Analogies (Agree)	100	100	*0*	80	100	*20*	86	All groups had high scores, with a positive change shown by it6 (not significant).
37. Metaphors (Agree)	80	93	*13†*	60	70	*10*	86	All groups had medium-high scores, and it4 (z=2.2645, p=0.023544), and it6 showed positive changes.
38. Indigenous knowledge (Agree)	87	87	*0*	40	50	*10*	86	It6 had slightly lower post-scores (though not significant), and small changes (not significant).
39. Numbers (Agree)	67	93	*27*	30	50*	*20*	75	it6 had different pre- (not significant) and post-scores (H

								(chi2): 4.992, p=0.0335). Both it4 and it6 showed positive changes (tests not significant).
40. Probabilities in odds (e.g, 1 in 5) (Agree)	73	87	*13*	70	70	*0*	57*	It5 had lower post-scores than the student groups (H (chi2): 5.01, p=0.0411). It4 had positive change, but not significant.
41. Probabilities in percentages (e.g., 20%) (Agree)	73	73	*0*	60	60	*0*	86	All groups showed medium-high scores, which were slightly different (though not significant).
42. Statistics (Neutral/Agree)	40	73	*33†*	10	40	*30*	57	All pre- and post-scores varied widely, but both groups showed high positive changes. It4 changes were significant (z=2.2711, p=0.023141), and it6 changes were not.
43. Audiovisuals (images and videos) (Strongly Agree)	100	100	*0*	100	100	*0*	100	All participants had perfect scores.
44. Maps (Strongly Agree)	100	100	*0*	100	100	*0*	100	All participants had perfect scores.
45. Graphs and plots (Neutral/Agree)	20	40	*20*	10	20	*10*	71	It5 had higher post-scores than it4 and it6 (not significant) and both groups showed positive changes (not significant).

* Kruskal-Wallis test for equal medians; non-parametric data

** Statistical tests were run on the original data (Likert-scale) not collapsed data (agree, neutral, disagree)

† Wilcoxon signed-rank test for paired data, for equal medians; non-parametric data

Appendix 6: Earthquake Content Knowledge

***Note**: The format of this information has been condensed to reduce the publication length.*

Instructions: Please answer the questions to the best of your ability, and ask the researcher if you need help. Please do not discuss the contents of this test with the other participants. Remember that this is entirely confidential and none of your instructors or peers will access this information.

General and Tectonics Scenario:

You are a seismologist. There has been a Mw 6.5, shallow (13 km depth) earthquake located 15 km west of a small community called Murchison. The earthquake caused damage locally, and was felt regionally. You are mandated by your organisation to communicate effectively to the public in the first 72 hours after the event. You will be interviewed by journalists about the situation, and so your Manager has asked you to report back with some working responses to possible questions. **Note**: It is important that you phrase your responses so they are suited to a general audience, and that you keep your responses brief.

Question 1. Why are some earthquakes damaging, and others not? What factors influence how an earthquake is felt at a given site (for each factor, provide an explanation of how it influences the shaking).

Question 2. As aftershocks continue to shake the region, the locals are worried about whether another, larger (>Mw 6) earthquake will occur. What should the community expect in coming months?

Hazards and Emergency Management Scenario:

You are an emergency manager. There has been a magnitude Mw 6.5, shallow (13 km depth) earthquake located 15 km west of a small community called Murchison on the West Coast of New Zealand. The earthquake caused damage locally, and was felt regionally. You are mandated by your organisation to communicate effectively to the public in the first 72 hours after the event. You will be interviewed by journalists about the situation so your Manager has asked you to prepare some working responses to their questions. **Note**: It is important that you phrase your responses so they are suited to a general audience, and that you keep your responses brief.

Question 1. When communicating with the 'public' it is important to know that there are many different stakeholders, with different needs. List some different stakeholders, and write some needs or considerations that are specific to that stakeholder during and after an earthquake event.

Question 2. The earthquake caused damage to Murchison (for example, liquefaction, facade collapse on buildings and damage to roads). List some essential actions and advice that the 'general public' (families, communities) will require immediately following the event. Explain why these actions and advice will be useful to the public.

Appendix 7: Pre-post Earthquake Interview Protocol

***Note**: The format of these interviews has been changed to reduce the publication length.*

Notes for Interviewer:
1. This is a scenario-based role-play between the interviewer and a student interviewee.
2. A digital audio recorder will be used to record the conversation.
3. To begin, read the instructions to the student, and allow them to review the questions, their role and the scenario. Give them several minutes to review, and answer any questions that they have before beginning.
4. Start the interview.
5. During the interview attempt to stay on script. Try not to interrupt the student, and give them as much time to answer as possible. Ask follow-up questions, if the student dodges the question.

Instructions:
'We are going to do an interview together. You will play a scientist, and I will play a journalist. Your main goal is to be an effective communicator.
'I will audio record this for research purposes. This interview is confidential, which means that no one will hear the audio or read the transcript except for the researchers. This will not affect your grades or performance in this course.
'I will now give you a paper that explains the roles we play, the scene, and the interview questions.'

Scenario 1: General and Tectonics Students

Roles:
Student – You are a seismologist. Your job is to answer my questions and communicate effectively to the public.
Interviewer – I am a journalist, who is recording your responses for the news, to be released as statements on national radio and in other media.

Scenario:
There has been a damaging earthquake on the West Coast of New Zealand. GNS Science has confirmed that it was a shallow (13 km deep) Mw 6.5 earthquake, with an epicentre approximately 15 km west of a small farming community called Murchison. * Point out where the earthquake has occurred and where Murchison is *. The earthquake occurred on 1 January 2015 in the morning, causing damage locally, and being felt regionally. State highway 6 has been closed as minor landslides have been reported. You have been flown to the West Coast (on the day following the quake) to assist in the scientific investigation of the event. I have contacted you because I am interviewing experts on the situation about the causes and effects of the earthquake.
Your statements will be broadcast on radio and in other media formats. It's important to know that this is not about having all the right answers, it is about communicating effectively.

Interview Questions/Script:
'Hi there, thanks for meeting with me today. I am here to ask you some questions concerning the earthquake near Murchison. The quotes you say will be recorded for the radio, and for other news media. I'll just start with my first question...

Question 1. So, I don't know much about geology, but can you explain to me and to the listeners, why earthquakes like this occur in New Zealand?
Question 2. The region is experiencing significant aftershocks. How long can we expect these to go on for?

Question 3. There have been reports of rock falls and minor landslides in the region. Why does this occur?
Question 4. Some people's homes in Murchison have liquefaction, but others don't. Why is that?
Question 5. Is there a chance that the Murchison earthquake will cause a larger quake on the Alpine Fault? Help the listeners to understand.
Question 6. Is there anything else that you think we should know about this situation?

Thank you for answering my questions!'

Scenario 2: Hazards and Emergency Management Participants

Roles:
Participant – You are an emergency manager. Your job is to answer my questions and communicate effectively to the public.
Interviewer – I am a journalist who is recording your responses for the news, to be released as statements on national radio and in other media.

Scenario:
There has been a damaging earthquake on the West Coast of New Zealand. GNS Science has confirmed that it was a shallow (13 km depth) Mw 6.5 earthquake, with an epicentre approximately 15 km west of a small farming community called Murchison. * Point out where the earthquake has occurred and where Murchison is *. The earthquake occurred on 1 January 2015 in the morning, causing damage locally, and being felt regionally. State highway 6 has been closed as minor landslides have been reported. You are assigned to the EOC (Emergency Operations Centre) in Westport to assist in the coordination and management of the event. I have contacted you because I am interviewing experts on the situation about the damage and effects of the earthquake.
Your statements will be broadcast in radio and other media formats. It's important to know that this is not about getting all the right answers, it is about communicating effectively.

Interview Questions/Script:
'Hi there, thanks for meeting with me today. I am here to ask you some questions concerning the earthquake near Murchison. The quotes you say will be recorded for the radio, and for other news media. I'll just start with my first question...
Question 1. When there is a significant, damaging earthquake, what are the first things that you must address, as an emergency manager?
Question 2. As an emergency manager, what is difficult about an earthquake event? How do earthquake events differ from other natural hazards?
Question 3. The Murchison earthquake occurred during the day. What are the things to consider when an earthquake occurs in the night, versus the day?
Question 4. People's homes in Murchison have been affected by liquefaction. What advice can you give them?
Question 5. Several farms along the highway have reported minor landslides on their properties. What should they do about it?
Question 6. After everything that has happened recently with the earthquakes, what can families do to become more resilient in these events?
Question 7. Is there anything else that you think we should know?
Thank you for answering my questions!'

Post-Interview Communication Questions (both groups):

1. Just now, were you using any communication strategies, if so, explain what you were doing.
    1B. What are you trying to achieve, what is the 'end goal'?
2. Based on the role-play exercise, what do you feel you've learned about communication?
3. Overall, do you feel you've become a better communicator? Why, or why not?
4. Any last comments or things you want to add about communicating?

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