UNIVERSITY OF SOUTHAMPTON

FACULTY OF LAW, ARTS & SOCIAL SCIENCE
School of Education

Students' Understanding of Earthquakes and Volcanic Events - A Cross-Age Study in Taiwan

by
Shih-Kuang Chueh

Thesis for the degree of Doctor of Philosophy

March 2007

ABSTRACT

This research investigates the development of concepts crucial to the scientific study of earthquakes and volcanoes amongst Primary school, Junior and Senior High school students in Taiwan, a country in which earthquakes are a common phenomenon and hazard. It investigates how children understand these phenomena and how their notions develop at different ages.

The data was gathered by means of a series of one-to-one interviews with students in Year 3 (age 8-9) and Year 6 (age 11-12) of Primary school, Year 3 in Junior High (14-15) and Year 3 in Senior High school (age 17-18). Additional data was obtained by asking all students to submit one drawing each of a volcano and an earthquake. Preparatory to the main research undertaken in schools in Taiwan, a pilot study was conducted with students from two of the same age-groups in England, as a result of which some modifications were made to the interview schedule.

The interview responses were analyzed according to experts' understanding of earthquakes and volcanoes and comparison was made across ages/study levels.

The analysis suggests that understanding of concepts proceeds unevenly with age, and shows that a significant proportion of concepts taught at a particular age may not be fully grasped by students. These findings lead to the proposal for a combinative learning model, in which young pupils could be supported in mastering important and essential concepts in the curriculum through the existing approach but older pupils supported by a rotational approach which also relates to the development of combinative learning.

The results of the main study have relevance for syllabus design and pedagogical practice in Earth Science, as currently taught in Taiwanese schools, as well as for earthquake preparedness amongst the general population.

LIST OF CONTENTS

Chapter 2 Literature Review 10

Chapter 3 Research Methods and Pilot Study 52

The Appendices

LIST OF TABLES

LIST OF FIGURES

LIST OF Schematic Diagrams

ACKNOWLEDGEMENTS

First of all, my special thanks goes to my supervisor Professor Mary Ratcliffe for her enthusiastic support, priceless tuition and encouragement throughout my course especially during times of great personal difficulties and also to Dr. John G Sharp for his guidance and advice at the beginning of this research .

I am also thankful for the students and staff who involved with my pilot study and main research at Taiwanese and British schools. With their assistance, I am able to collect a lot of valuable data for this study.

My appreciation still goes to a few individuals who inadvertently made me persist with my research in the face of the enormous obstacles which used to be placed in front of me.

Chapter 1 Research Outline

1.1 Introduction

This work concerns children's ideas about earthquakes and volcanoes. The main study in Taiwan involved children from four age bands (year groups). Earth science education has already been taught for more than 20 years in Taiwan. The content of the Earth science curriculum covers the lithosphere, oceanography, the atmosphere and the Earth's internal structure. In Taiwan, earthquake and volcano education is widely available, and students as a result are provided with the chances they need to assist them to come to learn about earthquake and volcanic events, to understand their causes and to deal with the results, especially of earthquakes in their local environment, they represent the most "immediate and practical of threats" and are serious hazards in Taiwan. The idea for this project (how students think about earthquakes and volcanic events and why they think thus) stems from the author's interest in Earth science following the 921 (geologists' reference to the 21st of September) earthquake events in 2000, resulting from Taiwan's location on an active tectonic plate boundary.

A clarification should be made here as to the nature of the two hazards (earthquakes and volcanoes). The catastrophe of earthquake in Taiwan was well-documented across the world in year 2000. Volcanoes, on the other hand, are a hazard that needs consideration, but also qualification. Basically, volcanoes are divided into the categories live, dormant and extinct (dead). Apart from muddy volcanoes, there are no live volcanoes (that have erupted in recent centuries) in Taiwan; there are many dormant ones (having erupted some hundreds of years ago). There is evidence of normal activity in the presence of hot springs commonly found in the country. Indeed, the natural beauty of the mountain regions and the presence of natural spas attract many Taiwanese visitors and school parties. The study of volcanoes can be an important part of the curriculum. This could be justified entirely on a geographical (national feature), geological and topographical basis. The land around the volcanic mountains is rich in mineral resources that have been extensively mined, but without concern for eco-tourism or the environment in general. Thus, any minor volcanic activity could entail large-scale commotion. But this commotion is subservient to other considerations in the thesis, which are knowledge of geology among students and general safety issues.

In the 1970s, students' concepts regarding earthquakes and volcanic events might not have been very clear, because there was no formal Earth science course; but nowadays Earth science is a specific subject from junior high school level. The detailed nature of related concepts and how students acquire and piece together items of knowledge in their learning about earthquakes and volcanic events in regular classroom teaching presents a large and potentially fruitful area of investigation. This project is to study the development of pupils' ideas as they learn about earthquakes and volcanic events from primary level to secondary level.

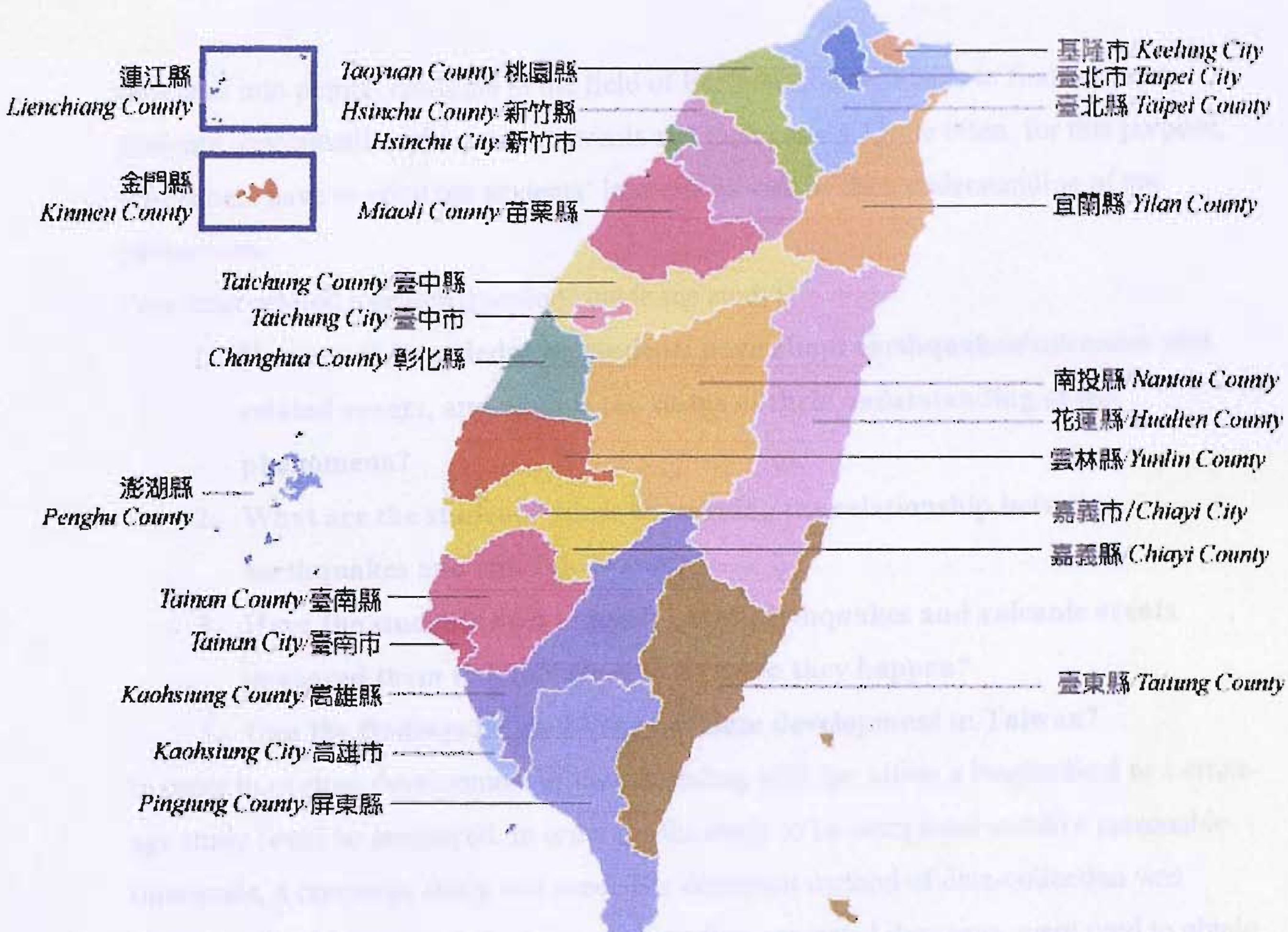
The research focus is thus on pupils' understanding of earthquakes and volcanoes and the implications for teaching and learning.

A cross-age study is chosen. As a background to the research, the Earth science curriculum in Taiwan is analysed to show the expected development of ideas. Findings from the detailed interview study can then be compared with intentions of the curriculum, to explore matches and mis-matches in learning. So that understanding at four different ages can be explored fully.

1.2 Location and participants

The children's ideas were elicited through interviews, which were carried out in the Great Taipei area of Taiwan. The participating primary school is located within Paitou District (which is in the north-west of Taipei City). The junior level and senior level schools involved are in the Shih-Lin District, which is in the north-east of Taipei City. These schools are average sized state schools. Students' academic performance is variable, and students invited to participate were picked from different academic levels (as explained in Chapter 3), the reason being that by this kind of "average" selection, the results of interviews are more representative and open to generalization. The project on the other hand actively avoided carrying out interviews in private schools, precisely because most private school students are selected for their high academic level; for this reason, if the project were to include private school students in the research sample, the results of the interviews would not be representative of schoolchildren's concepts in general.

Figure 1.1 The location of Taipei, Taiwan



The participants in the main research were 25 year-3 and 25 year-6 students (primary level), 25 students from junior level (year 9), and 25 students from senior level (year 12). Each level contained a mix of boys and girls, and the 100 students were between 9 and 17 years old. The names of the students are not revealed to protect their privacy and to conform to the pledge of anonymity. All interview processes were carried out in a single room in each school, and just once for each individual student.

1.3 Research questions

Research into pupils' concepts in the field of Earth Science attempts to find out how students conceptualize phenomena, events and their causes. Quite often, for this purpose, researchers have to elicit the students' interests as well as their understanding of the phenomena.

Four inter-related research questions guide the study:

1. **How much knowledge do students have about earthquakes/volcanoes and related events, and what is the status of their understanding of the phenomena?**
2. **What are the students' ideas concerning the relationship between earthquakes and volcanic events?**
3. **Have the students own experiences of earthquakes and volcanic events prepared them to know what to do when they happen?**
4. **Can the findings be used in curriculum development in Taiwan?**

In order to explore development of understanding with age either a longitudinal or a cross-age study could be employed. In order for the study to be completed within a reasonable time-scale, a cross-age study was used. The dominant method of data-collection was interview in which multiple techniques, including annotated drawings, were used to obtain evidence of pupils' understanding. Details and justification are given in Chapter 3.

1.4 Theoretical and analytical framework

This research is based on constructivist frameworks of development of understanding of concepts (Chapter 2 contains discussion of the theoretical framework).

Earthquakes and volcanic events can be regarded as a complex of phenomena involving related objects and natural events. The objects, events and phenomena form conceptual categories essential in communication of knowledge about them. This research tries to gauge both the variety and clarity of thought and understanding of students. The variety or clarity can be used as an indication of their grasp of multi-concepts regarding the phenomena, and, if students show a lack of such thinking, they may be presumed not to have acquired the concepts from the curriculum. Evaluation of pupils' understanding may provide useful information about the conceptual challenge of learning about earthquakes and volcanic events as both geological phenomena and events which can have societal impact.

1.5 Science and Earth Science National Curriculum at primary, junior and senior levels.

The National Curriculum provides a background for the expected development in learning. Nowadays, Primary science in Taiwan is a multi-Science curriculum, which includes Chemistry, Physics, Geography, Geology, Astronomy, Atmosphere science, Oceanography and Biology. More than 90% of the textbook material is concerned with Chemistry, Physics and Biology, and only about 10% with Earth Science. The textbook's material directly related to earthquakes/volcanic events comprises less than one complete chapter (only mentioned in Chapter 3 Our Home-Earth).

In Junior and Senior high school, Earth Science is a specific and compulsory subject for students, but the material dealing with volcanic events and earthquakes is still limited. The concepts of earthquakes and volcanic events from primary level to senior level as they occur in the textbooks, seem to be inadequately linked (more detail will be given in Chapter 2), and although there are practical exercises in the secondary textbooks, it seems that most teachers and students hardly focus on them (according to teacher's handbook, these practical exercises are optional. And many primary teachers told me that they hardly asked pupils to do these exercises). This might make it difficult to raise interest and motivation. Sharp et al (2002) maintains that "Primary science is regarded as an intellectual, practical, creative and social endeavour which seeks to help children to better understand and make sense of the world in which they live by involving them in thinking and working in particular ways in the pursuit of reliable scientific knowledge". This viewpoint is particularly relevant to Earth science at junior and senior level, where there is a clear need to increase pupils' curiosity and thirst for knowledge. It is almost impossible for an adequate understanding of Earth Science at junior and senior levels to be achieved through theoretical study only (the teacher's hand books suggest that a complete conceptual understanding in general science should be carried out by both theoretical study and practical exercises). Students' understanding of volcanic and earthquake events could be developed in different ways.

1.6 Creativity of the Research

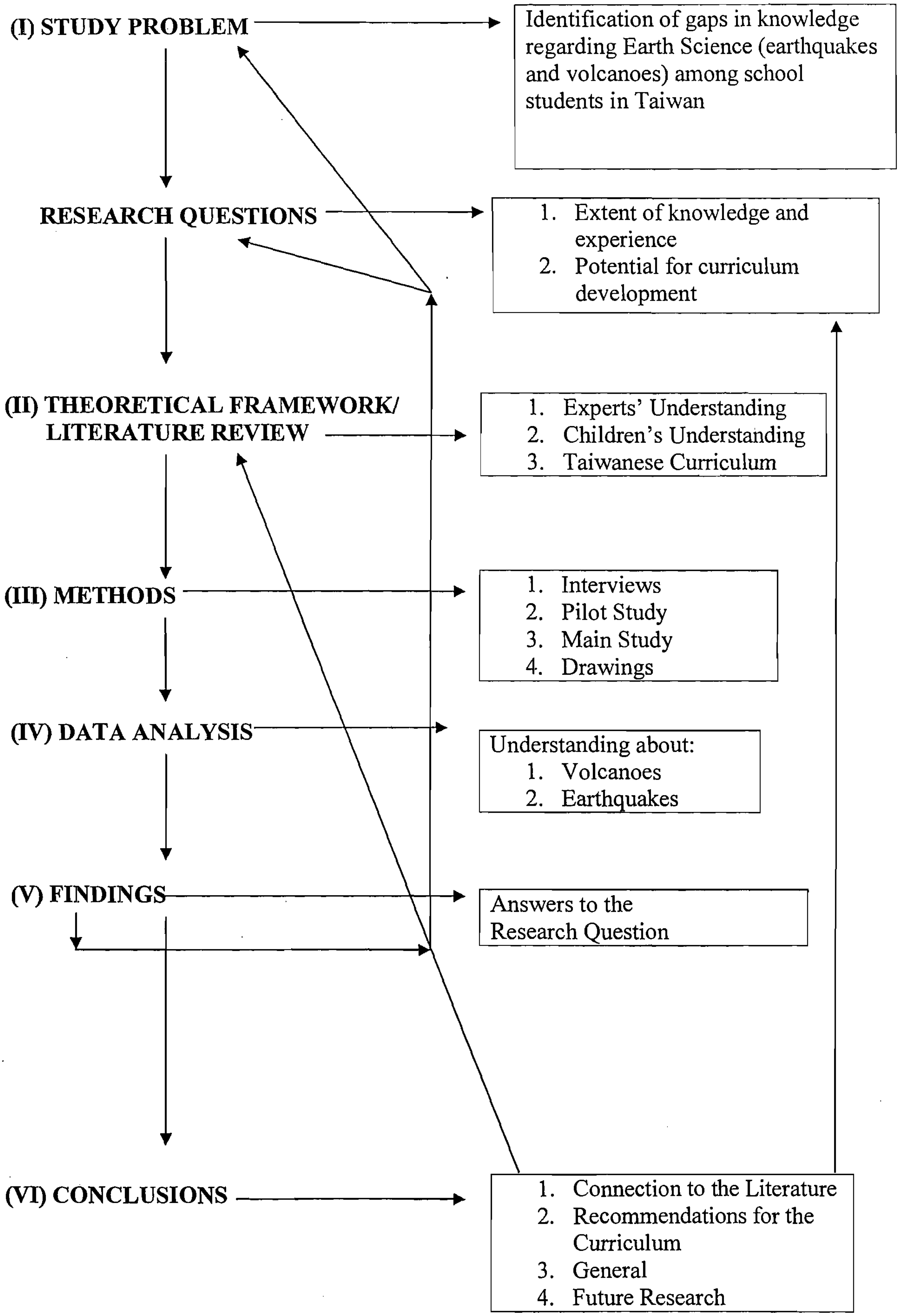
This research can be considered original in several ways. Although the study of pupils' conceptual development is not new, those specifically regarding earthquake and volcanic events have not been investigated from primary level to senior level in Taiwan, or even elsewhere. Interview studies and cross-age studies of knowledge acquisition/understanding, and conceptual development are unusual, and, in recent years especially, have not been undertaken seriously within Taiwan. The range of earthquake activity is broad, with considerable relevance to students' daily lives and the local environment. Hence the research will also concern students' understanding of plate tectonics, the Earth's internal structure and the various kinds of geological stress, all of which, studied systematically, should result in a fuller perception. Taken as a whole, it is hoped that the research will provide an opportunity to reconsider active Earth Science teaching and possible modifications to the curriculum.

1.7 Summary

Research on students' ideas in Earth Science education generally attempts to find out how students conceptualize the natural environmental events and the phenomena of geological study by means of eliciting their ideas, thoughts and understanding. Multi-method interviews are a useful technique for data collection. The cross-age study presented here endeavours to examine, in such a way, students' ideas more specifically regarding earthquake and volcanic events and to investigate how/why these ideas alter as a result of conceptual development in the context of study in Taiwanese primary and secondary schools. The research attempts to do this through "field work" undertaken in four age bands in state schools in Taipei (interviews and data collection). The student participants included 100 students from primary to senior level. There were 25 students from each stage (Year 3, Year 6, Year 9 and Year 12); and each stage contains high, medium and low achieving students. In Taiwan, educational policy does not discriminate between more or less able students, and classes in all state schools from primary to senior level are of mixed ability. The three schools are likely to be representative of students' status and performance throughout the area. The interview was designed to investigate their understanding of key concepts and conceptual structures (the most basic and the most important) in Earth Science (earthquakes and volcanic events), through relatively simple verbal and visual expression. The study of Earth Science, and, more particularly in the context of this research of earthquake and volcanic events, is conceived here in broad, practical terms and as part of an educational process that is intimately related to the real-life concerns of the students and the local community, seeking to bring students to a clearer appreciation of the roles and relevance of geological movement to their own lives and their own immediate environment, in the pursuit of reliable knowledge through scientific method.

In the following chapter I first review the literature that seems most relevant to this study, looking at research that has already been carried out on children's ideas in science generally and more specifically in the fields of geo-science and Earth Science, and narrowing that down to research on particular topics and notions, including those of earthquakes and volcanic events. The textbooks that are used in Earth science education in Taiwan are also reviewed. The succeeding chapters present the study methods, the study results and the conclusions.

Schematic Diagram of the thesis



Chapter 2 Literature Review

2.1 Introduction

The purpose of the literature review is to obtain an overview of the field of research and to clarify perceptions of the methodological issues, as well as the thinking behind the research project as a whole. From initial points of departure in existing work, the review may create a space in which to draw and test new lines of enquiry and the review may expand upon the context and background to the research area.

This chapter highlights children's perceptions about general science, Earth science, and specifically volcanoes and earthquakes. The implications of this research, for the teaching and learning of Earth science also constitute an important topic.

The first purpose of the literature review is to consider a theoretical framework for the research in terms of learning theory.

2.2 Learning theories and Children's ideas in Science

This section outlines constructivism as a learning theory and its use in research relevant to my study. Ascertaining children's perceptions about science topics has been a very active and fruitful area of research over the past 30 years (Hodson, 1998). It is significant and perhaps fortunate, too, that there appear to be certain kinds of understanding held in common by children. Imagine the task facing a teacher, Hodson points out, if there were no common elements in children's understanding. The beliefs that children hold prior to instruction have been variously termed: alternative frameworks, alternative or prior conceptions, mini-theories, naïve theories, children's science and so on.

Students' may build ideas according to the theory of "constructivism". Piaget (1932) proposed the four-stage theory of intellectual development, according to which a child is only able to grasp a particular concept when a prior concept has already been attained. For example, intellectually, the metaphorical usage of a word cannot be understood until the concrete meaning has been grasped. The four stages Piaget identified are:

First of all, in the sensori-motor phase (birth to about age 2), children learn from information which they gather directly through their senses and physical experiences;

secondly, in the pre-operational stage (from about age 2-7), children reason directly from what they perceive, though their reasoning may not always be logical. The third stage is that in the concrete operational stage (from about age 7-11), thinking becomes characterized by logic and does not require real objects to be to hand. The characteristic of thinking which most significantly marks the transition to this stage is the ability to conserve, to see that quantities such as mass and volume (for example) remain constant in operations. This age range corresponds in my research with Primary level, and the fourth stage is that in the formal operational stage (from about age 11 onwards), children become capable of abstract thought and are able to grasp ideas such as those involved in the control of variables and ratio and proportion. This corresponds to Secondary level in my research. These four stages of identification represent a background to my research, particularly from age 7-11 and age 11 onwards. I think that Piaget's points of view might help me to look at my data closely.

Nowadays, Constructivism can be regarded as one of the classic theory for explaining how students learn. Piaget was the initiator of a constructivist view of learning focusing on explaining how pupils construct new knowledge/concepts from existing knowledge/concepts. Many scholars subsequently developed versions of constructivism. For example, Holt's (1995) ideas on students' learning tie in with constructivist theory; he believed that most children construct knowledge through a number of aspects, such as games & experiments, talk, reading, sports and art, which are useful catalysts to students' learning procedure and knowledge construction.

Firstly, Holt believed that children's learning depends very much on their mood. He was concerned about pupil mood changes over a short period of time and recommended taking off the pressure, reassurance consoling, giving time to re-group, "As in time they will have enough energy and courage to go back to the task". Holt believed that students could learn well if in a good mood, which can be fostered through playing games, exercising and experiments. This point of view can help me to inspect the connection between students' learning and live activities (games & experiments) in my research; for example: many pupils in Taiwan regularly have earthquake exercises at school and have experience of earthquake simulators at the museum or school. These are sort of live activities and experiments. Holt's point of view suggests to me to look at whether or not such activities help students to learn about volcanic and earthquake concepts. In other words, they may contribute towards the construction of knowledge.

Secondly, Holt believes that "Talk" is also a very important learning element for children. "Talk" may be additionally seen in my interpretation as including written communication (children expressing themselves in words). Holt indicates "A child who does not talk will not have many things that he wants to say, and hence will not know what to write about. He will often feel that nothing he might want to say or write could possibly be of any interest to anyone else, and that if he did say or write something, others would only laugh at it. As fast as thoughts come to him, he censors them, rules them out. When he does try to express his thoughts, he finds it hard, because he has had so little practice in putting words together". Holt suggests that good self-expression can improve children's learning in an effective way. On the other hand, if children feel difficulty in self-expression, this might indicate that they have not learned enough. I believe that this point of view suggests that different forms of expression can be used to elicit the greatest amount of information. In this study, drawings can be used to supplement data from interviews with students. Also, during the interviews, I can observe how students express their understanding about earthquake and volcanic events through their natural reactions, such as body language, verbal language, tone, and eye expression. These multi-expressions could be helpful in understanding pupils' understanding.

Holt points out that students may obtain stimulation through sports or live activities. Holt believes that students can obtain new knowledge or skills in practical activities, or experience something in person. In other words, these sorts of new knowledge and skills can be picked up by students while relevant activities are being carried out at the same time. In terms of practical experience, there are many tangibles in my research field relating to the earth's movements. For example, students in Taiwan might have the chance to make a geological tour; they might have a chance to visit a mud volcano, a hot spring pool, a lagoon, or a reverse fault. These geological phenomena are caused by volcanic and earthquake movements. Nowadays, many of the above phenomena have already become tourist attractions. People are allowed to jump into the mud volcano and enjoy the warm mud. It attracts female tourists interested in skin care. Some children enjoy playing and swimming in the hot springs or fishing in lagoons. Hence, students might increase their volcanic/earthquake knowledge while they are enjoying these geological tours. Tourist

guides or other tourists might introduce some relevant knowledge to them. Holt's ideas suggest to me to scrutinize the data from my research with this point in mind.
Holt believes students' artistic expression shows how they learn, observe and gain knowledge, because, in drawing, students need to observe, learn or maybe copy the very basic features of the object. The procedure constitutes learning. I feel that these points of view related to art can be used to check and confirm students' conceptual and knowledge development, and I believe that the idea of picking up the characteristics from students' annotated drawings can be useful to my research.

From the significant body of early research undertaken within the constructivist or "alternative frameworks" movement, Driver and Bell (1986) argue that children form their own ideas about the world in which they live long before any formal teaching takes place in school, those ideas frequently differing from the science taught at school and the ideas of scientists themselves. They consider that the ideas can be strongly held and resistant to change even in the most supportive, caring and stimulating of learning environments, but when they do change, it can often be in unanticipated ways, with what the teacher intended being at odds with what the child perceives.

According to Driver and Bell (1986), the main features of constructivism are building the knowledge of the learner within the school learning environment, learning involving the construction of meaning. They go on to indicate four features of constructivism. Meanings constructed by students from what they see or hear may or may not be those intended. Construction of meaning is influenced to a large extent by the existing knowledge of the learners. Furthermore, the construction of meaning is a continuous and active process, and meanings, once constructed, are evaluated and can be accepted or rejected. Finally, there are patterns in the types of meanings students construct due to shared experiences with the physical world and through natural language.
These main features of constructivism will be borne in mind during my research.
Driver (1981) also indicates that largely because of the insights offered by constructivism, the passive role of children in science learning, which assumed children to be merely empty vessels waiting to be filled, is no longer considered acceptable.

Scholars, including Driver et al 1994, have developed constructivism further. Driver et al. (1994) identified several possible forms of development that relate to constructivism. The

first point is about developing existing ideas as long as no misunderstandings appear; the second point is differentiating between existing ideas (where two or more scientific ideas may have been seen as one by pupils, a learning phenomenon known as dissolving and melting, which can be exemplified in my research by the confusion of, for example, lava and magma); the third point is about integrating existing ideas (where pupils may hold several ideas relating to one scientific idea). The above points are helpful in looking at pupils' existing ideas and their conceptual development, differentiation and integration, for example, in the building of a more complete picture of a range of phenomena, like earthquakes, tremors and landslides. The fourth point is about changing existing ideas (where pupils hold ideas which differ from the scientifically accepted ideas). Trend (1988) suggests: "It is well embedded in the constructivist view of learning that new learning is dependent on existing understanding". It seems that Trend's suggestion is a practical idea to look at how students may have relevant concepts about earthquakes and volcanic events and check whether or not (by asking additional and coherent questions), as time goes on, students would revisit existing concepts and see if they are able to connect new concepts with existing ones. Although the above points of view did not appear in Piaget's (1932) theory----four stages, Driver et al (1994) believed these were learning possibilities developed from Piaget's theory.
Driver (1994) has mounted a robust defense of constructivism in science education. According to Driver, the view of learning science as acts of personal and social construction does not imply relativism (an often voiced concern) but realism. This acknowledges the more scientifically acceptable view that scientific knowledge is constrained by how the world is and that its knowledge claims are considered to reflect or work towards that reality.

Referring again to Driver (1994), if children are to adopt scientific ways of working and knowing, then intervention and negotiation of meaning with a teacher are essential if the cultural tools and conventions of the scientific community are to be made available to them. As Driver pointed out, "the challenge is one of how to achieve the process of enculturation successfully in the round of normal classroom life, particularly when the science view that the teacher is presenting is in conflict with the learners' prior knowledge schemes." Learning that is characterized as a straightforward process of knowledge acquisition, conceptual change and the associated generation of new meaning or sense-making may however be overly simplistic. Driver (1994), for example, suggested that children need not

be expected to abandon their "alternative framework" or common-sense ideas as a result of science teaching. Instead, they should have these new ideas available to them for communication within appropriate scientific contexts, even whilst continuing to use common-sense ideas within their own “common-sense contexts”.
My research aims to explore the frameworks that pupils have about earthquakes and volcanoes in order for these to be developed further through sensitive teaching.

A number of constructivist approaches to science teaching and learning have been developed (Cosgrove & Osborne, 1985, Driver, 1989, Harlen, 1992, Appleton, 1993). While they differ a little in detail (as I mentioned earlier, Piaget's constructivism has not been universally accepted as a learning model), their prescriptions can be usefully summarized as including:

- Identifying students' ideas and views
- Creating opportunities for students to explore their ideas and test their robustness in terms of explaining phenomena, accounting for events and making predictions.
- Providing stimuli for students to develop, modify and, where necessary, change their ideas and views
- Supporting their attempts to rethink and reconstruct their ideas and views.

Of course, there are some topics, phenomena and events of which children may have no prior experience and for which they will not have formed any prior views.
Steffe et al (1995) believed that any epistemic improvement must be constructed from students' clear understanding; in other words, if students' existing concepts are not clear, no further concepts/knowledge can be constructed on the existing concepts without a gap or disconnection in understanding. Steffe's point of view suggests to me that some students might have a general understanding of earthquake or volcanic phenomena, but their understanding might not be connected well. It might also be that students have a different level of understanding in each key concept. Spivey (1997) applies another constructivist theory to explain why students might have a different level of understanding in different concepts. Spivey says that when students read texts alone (before any instruction), it is like reading a metaphor, of which each student might have a different understanding/comprehension, so that when teachers might give a formal lesson on the

subject, the students do retain part of their own understanding/comprehension. The first impression contributes to the construct of knowledge, concepts or belief, and it will take time to alter it.

Spivey believed that different comprehension of the texts causes students to create different meanings for texts and hence they might have a different construction of the knowledge/concepts. As soon as pupils read or write (practical exercise) part of the texts, they might link certain parts of what they have read or written to one of their existing knowledge, and this is called making of meaning (ibid). Spivey's view provides a good point of interest for my research. I can check whether or not students do understand the connection between phenomena and causes by asking coherent and additional questions in the interview.

Larochelle (1998) believed that pragmatism and epistemology are two related and useful bases of conceptual construction. He indicated that students might be able to make a connection between theoretical concepts and practical experiences, but it is difficult to make a connection between theoretical concepts and phenomena they are not familiar with. In other words, Larochelle suggests that a complete construction must be based on familiar concepts and practical experience. Larochelle's theory along with Spivey's view also generates for me the idea of looking at whether Taiwanese students are able to connect the implications of earthquake nature (theoretical concept) and their attitude (practical experience) to earthquakes, as compared to volcanic events, of which they usually have no experience, by asking additional related questions.

Selley (1999) demonstrated that classroom experience, for example reading and writing, could influence children's learning outcomes, she believed that these classroom experiences provide practical exercises to support learning, and from these practical exercises students seem to obtain a clearer impression of concepts and construct a relatively solid understanding. Both Selley (1999) and Spivey (1997) emphasize the importance of practical exercises in the constructivist framework. Spivey emphasizes that the practical exercise should be complete, incompleteness perhaps causing conceptual misunderstanding or mis-construction. Selley focuses on the idea that practical exercise is vital in completing conceptual construction of new knowledge based on existing knowledge. As I mentioned earlier, the pupils in Taiwan might not have enough practical exercises. Both Selley and Spivey's points of view might help me to look into my data.

2.3 Children's ideas in geo-science and general aspects of Earth science

Researchers have used the ideas of constructivism (described in section 2.2) to explore pupils' understanding of many scientific concepts. This section considers such research relevant to my study.

A considerable amount of information is now available about alternative conceptions in the general geo-science field and their implications for students. Before students understand the range of Earth science fully, the meaning of general geo-science could possibly be described as "whole world phenomena" rather than any specific field. In other words, real world phenomena interweave and interact in ways too complex for children to grasp at a young age. Their ideas may be naïve or vague and quite general. I outline the literature on some children's ideas of general geo-science below, according to various authors writing on topics such as river systems, soil and landscape.

2.3.1 Children's ideas in geo-science

Children have some interesting ideas in different areas of general geo-science, Dove (1996) points out that children's ideas of Geography (basically a part of geo-science) stem from children's literature, maths, science, art and a whole world of activities. Dowd (1990) believes that folktales as a genre of children's literature are a source of information about geography, since their origins and settings are traceable to a particular geographical region. The words as well as the detailed and authentic artwork reveal many interrelationships between people and their environment, for example, common crops and foods, house types, clothing styles, vehicles, typical occupations, recreational activities, and indigenous flora and fauna.

Cullinan (1989) has some suggestions as to how such sources of knowledge may be actively used: after reading or hearing several stories from the same country or culture, children in third grade could make a chart with categories labelled, (i.e. landforms, animals, place names, climate, foods, dwellings, and so on) and they could include in it geographical facts gathered from the books about that particular country; or the classroom teacher and the school librarian may team together to locate and share with students several variants of the same basic folktale from different countries, from which they can fill in the charts and compare and contrast the geographical information revealed about each country in which a version of the story is set (Cullinan 1989).

In Good's research (1963), the purpose was to obtain some facts about the ability of secondary school children to recognize geographical features shown in photographs (at Polperro and Shieldaig). Good (1963) indicated that the results (students' pictures) showed that although there were only two geo-phenomena shown to the pupils, the children "chose" to see what they believed to be the "real geo-phenomena". What these particular children actually saw, undirected and unaided, of geographical significance in these pictures, would appear as follows.

In the Polperro picture an average of 74 per cent saw rocks, the harbour and houses as “geo-phenomena”, 43 per cent included the valley, wooded slopes and cliffs. Other significant features were apparently lost to them. In the Shieldaig picture, approximately 70 per cent identified the cultivated land, and 40 per cent the wooded slope. It does not appear that the eye of the child sweeps, as does that of the geographer, to the 400-foot platform of the Polperro picture or to the raised beach of Shieldaig, which were the geo-science phenomena of major interest.

Teaching that uses visible or tactile objects may reduce the chance of misconception among students. Catling (1994) commented that most children have seen photographs of the Earth from space, but using a globe gives children the opportunity to hold the Earth in their hands, to look and see what is there, to get a sense of its shape and to begin to find out what is on it.

For some children, looking at the land and water, seeing their shape and labelling them will be their starting point. For others, it will be finding where family and friends have visited, and these places can also be labelled. Linked to some geographical and other work will be opportunities to show where different kinds of environments appear on the Earth, such as deserts or glaciers; from these activities, students enhance their basic view of world locations.

Students' ideas in geo-science are quite complex but nevertheless traceable, as can be seen from some of the existing research results described above. The following section narrows down the geo-science range to children's ideas on Earth Science, to see if and how their ideas and especially their misconceptions can be traced. The main purpose of reviewing children's ideas in geo-science is because their knowledge range in geo-science is broader than that in Earth science but narrower than that in general science. In this circumstance, it is useful for me to understand how students handle some relevant knowledge. Here, relevant knowledge means knowledge of geo-science that closely relates to knowledge of Earth science and is much more specific than general science.

2.3.2 Pupils' perceptions and annotated drawings in general Earth science topics

The major difference in my view between Earth Science and Geo-science seems to be that Earth Science usually does not include the area of geography, but does include the overlap between geography and geology.

Larson and Birkland (1982) noted a common misconception involving the Earth's layers and processes that has been found among many students, namely that molten earth material, magma, originates in the Earth's very hot core. The study of earthquakes or seismic wave behaviour strongly suggests a liquid and, therefore, a very hot outer core. Without further study, it is tempting to conclude that such material can, at various times and places, work its way to the surface and erupt as lava from such features as volcanoes and fissure flows. In reality, virtually all magmas are thought to originate in the upper portion of the mantle and crust. Melts appear to be generated primarily by frictional heat accompanying fault movements associated with plate tectonics. Larson and Birkland's research indicated that the pupils might have misconception from similar phenomena which actually originate from different factors (the magma originate from hot core and the magma originate from the upper portion of the mantle).

Oversby (1996) conducted a study on children's understanding of fossils, through annotated drawings. Coal was understood to be a fossil by the great majority of pupils and has been described as a fossil fuel for a long time. A more useful view however is that coal is rock containing fossils. The view that "coal is a fossil' is common, but one that needs further investigation. A petrified body was also thought to be a fossil, but a significant minority of students disagreed. An unchanged shark's tooth for example gave rise to greater uncertainty, with a majority of pupils holding the view that it was not a fossil. Similarly, whether a footprint is a fossil was open to considerable discussion. In this case, only an impression remains, rather than the living creature itself. A frozen mammoth appeared to be the least convincing example of a fossil. From the above students' views, it seems that only living things that have undergone some transformation are easily accepted as fossils; biological vestiges or unchanged living things are not. It can be seen that students' concepts about earth science are quite subjective and often revealed in their annotated drawings.

Studies of drawings date back at least thirty years (Chula,1998). Chula (1998) argues that: "What is significant ...comes across again and again in the drawings or paintings that a child makes more so than is the case with much of what passes for 'verbal' communication." Chula argues that drawings are a tool for literacy development, "establishing a relationship between visual/verbal symbol systems." She cites a large number of authors who regard drawings as a means of assessment of pupils' knowledge (p.9) and a "pathway to understanding" (p.10) how children perceive the world. Drawing frees the mind from the restrictions of verbal thinking (p.10). Symbolic drawing as part of an exercise or task reduces the effects of the "I can't draw" attitude, as the task is very simple and the motive is direct (p.23). It thus may be useful to use annotated drawings as a tool in my research to show pupils' understanding.

2.3.3 Map skills –Pupils' ability to indicate the location of earthquakes and volcanic events

To understand the nature of earthquakes and volcanic events is one thing, to indicate where they happen is another. Some pupils might be able to talk about where earthquakes and volcanic events usually happen on Earth but it doesn't mean that they are able to indicate the correct location from a map or a globe.

Wiegand (1998) indicated that sometimes children lack an understanding of the relationship between the round earth and a flat map. Australia was more accurately located on a plane surface map than on a spherical surface globe. This may be because of its more memorable location in the "bottom right" of an Atlantic-centered world map compared to the difficulty of visualizing its location at the antipodes of a globe. Antarctica, however, was more accurately located on a spherical surface than a plane one. When working with a globe, Wiegand (1998) found that children appear readily to establish the positions of the poles and thus Antarctica becomes an early reference point. The unresolved appearance of Antarctica on most world map projections seen by young children is thought likely to add to some confusion about its location when reference is made solely to a map. Wiegand (1998) studied seventy-two children from six primary schools (in the U.K.) who were invited to draw the Earth's land masses on a blue sphere, representing a globe. Cox (1992) indicate that drawing on a spherical surface appears to offer potential in helping to illuminate significant facets of the development of children's understanding of spatial relationships while reconstructions were creditable. They showed a tendency to represent Europe-Africa as a single land mass, Africa as a continuous southward extension of Europe, and Europe-Asia as separate land masses. Best shape retention on a globe was for North and South America and Antarctica and poorest shape retention was for Africa and Australia. Relative location was also most weakly reproduced for Africa and Australia. These effects were thought to be a result of the partial viewpoint obtained from a globe, compared with the view of the whole world obtained from a map. The shape of the Earth might be quite inconstant, especially when students transform a global image into a flat image or vise versa.

Wiegand (1998) also indicated that many children appear to believe that Europe is physically separate from Asia. This tendency was noted on spherical surfaces through free recall maps and the positioning of cut-out shapes. Free recall drawing and template positioning on plane and spherical surfaces also indicated a tendency to locate Europe too far south. This has the effect of forcing children to misplace or misalign Africa because insufficient room has been left for it. From the result of Wiegand's research, it seems that Africa was the continent most likely to be omitted from sketch maps on both plane and spherical surfaces. Using templates, it was the least well located and most inaccurately orientated continent on both maps and globes.

Van Sommers (1984), however, believed that freehand sketch mapping from students, whether on a flat plane or a sphere, is not without its methodological problems. It involves interaction between motor co-ordination and the consultation of an "inner image" or representation from memory of the world. Thomas (1995) refers to the schemata that children often learn as formulae for making pictures of familiar objects. These include a flattened "m" shape to represent a flying bird and stacking two circles (with the addition of ears and a tail) to create the impression of a sitting cat. Wiegand's (1995) study involved a relatively small number of participating children, but some tentative conclusions may be drawn. There do appear to be age sensitive changes in the way children depict the earth, but exactly what the interplay is between the development of children's thinking and the way that thought is represented remains imperfectly understood.

Map skills have proved a useful way of revealing pupils' notions about the shape of the Earth. It is easy to observe how they think that the continents are distributed over the Earth's surface. Blaut (1997) draws attention to maps as spatial representations; he found that even preschoolers are able to demonstrate some understanding of the geometric correspondences between map and space. For example, under some circumstances, they are reasonably good at recognizing correspondences between a location shown in a room and a location shown on a map. The conclusion of Blaut that children have only a limited understanding of the geometric correspondences between map and space pertains not only to small scale map skills but also to large map skills, such as continental distribution and the Earth's shape.

To go back to Nussbaum and Novak's (1976) early research, most of the investigations making such claims were largely developmental in nature and few of the authors described any of the children involved as having been exposed to instruction specifically targetting the Earth as a cosmic body, other than what they might have encountered incidentally or through existing curriculum provision at school - the details of which for science were sketchy to say the least. Other studies of ideas involving primary aged children up to 11 years of age from Israel, America, Australia and England, and deaf children from Norway, exposed to more explicit cultural transmission and formal instruction, uncovered similar models to those presented earlier, but the profile of the models obtained differed substantially among these studies, particularly those involving Australian and English children, of whom between 70 and 95% were found to exhibit scientific conceptualization by age 8 (though only about 50 to 55% or so with respect to gravity).

Vosniadou and Brewer (1992) indicated in their work that an intuitive 'flat' Earth stage always preceded scientific conceptualization. Butterworth, Siegal and Dorfmann (1997) found little or no evidence that this was in fact the case. Instead, they suggested that even with children as young as 4 years of age, particularly those raised within an 'Australian immigrant culture', direct cultural transmission played a significant part in Earth shape development. Globes, atlases and relatives living in the northern hemisphere were often mentioned in children's justification of Earth shape and answers seemed to genuinely reflect understanding rather than the simple repetition of overheard and ill understood facts.

Students' ideas about the shape of the Earth are likely to have a bearing on how they approach geo-science. As I can see from the previous research, for young pupils especially, to understand the Earth's shape is indeed a milestone in understanding Earth structure. And thus it can be first contact for students with more specific knowledge about general geo-science, from Geography and Topography, to Earth science. The understanding of the Earth's shape is a bridge to a closer view of what Earth science might be. As the shape of the Earth is a good elementary topic to introduce students to more specific Earth science, the shape of the Earth provides a good connection between Earth science and geo-science, and this is its key value in probing students' ideas about the general structure of the Earth. The literature review continues by looking at students' views of the following topics: rocks, earthquakes, volcanoes, and the Earth's structure---as these are the main focus of my study.

2.4 Experts' understanding of volcanoes and earthquakes

As my research focuses on pupils' understanding of earthquakes and volcanoes, it is important to have points of reference to judge pupils' perceptions. Thus, I consider the views of experts, geologists, in clarifying the specific concepts which I am studying. Pupils' perceptions can then be compared with the expert view in order to judge the nature of their understanding.

This section is about experts' views in earthquake and volcanic events which I synthesize and integrate from a teachers' handbook 1-5 (Chen & Liu, 2002), and other publications in general geology (Rothery, 2000). I expect to see that pupils are able to indicate the following geological terms with general ideas (not necessarily in detail), and connect any relevant concepts together with these terms as well. The reasons that I have these expectations are because first of all, Earth science is an obligatory course in junior and senior high school, therefore, the secondary students should be able to indicate the relevant knowledge in general. Secondly, although there is no Earth science teaching in Primary level, but there are some relevant concepts introduced in the general science text, hence, Primary pupils should be capable of describing some relevant phenomenon.

2.4.1 Volcanoes

1. Magma origin and eruption

Magma is less dense than solid rock, when it is formed (basically it is molten rock). It can be pushed to the surface by the Earth's internal pressure. Some magma bodies cool down before they reach the surface, a process called intrusion, which means that the magma intrudes on other layers, and may bring about regional metamorphism. When magma reaches the surface, it may ooze out and start to flow downhill, which is described as lava flow. In other words, once magma is on the surface, it is called "lava".

2. Magmatic gases and eruptive conditions.

The main reason for lava exploding is the sudden escape of gases dissolved within the magma. When the gases move quickly, the bubbles may expand by huge amounts. The activity is like that in a can of coke after having been shaken vigorously. The surface area of each bubble increases, as the sticky magma is brought up to the surface. When the bubbles reach the Earth's surface, the external pressure on them reduces immediately, causing the lava to separate.

During the above process, the bubbles also bring up other material and ash (volcanic ash). A typical volcanic eruption usually contains different gases with volcanic ash and lava. The typical gas composition is about 56% water vapour, 28% carbon dioxide, 14% sulphur dioxide and 1% or maybe less of hydrogen sulphide, hydrogen chloride, hydrogen and carbon monoxide.

Whether a volcanic eruption is explosive or calm depends on how quickly the magma rises and how easily the gases can escape. In many volcanoes, gas escapes quietly over hundreds of years, and there may never be any associated eruption. This can depend on the nature of the magma. If the magma is very viscous, the speed of the rising bubbles will be slowed down; in this situation, when the enlarged bubbles reach the surface, the eruption will not be quiet, the noise being created when they escape from the sticky material. Basaltic lava has the lowest viscosity, and it often oozes quietly; granitic lava has the highest viscosity; hence, it seldom erupts quietly. Andesitic lava is in between.

3. Volcanic hazards

Lava flow can cause tremendous damage to property; however, it rarely kills people, because, in fact, the lava flow advances at only a few meters per hour, and after 10 kilometers, the speed of flow is even less.

Another volcanic hazard is volcanic ash. Ash is a heavy dust which can appear in any of three ways: in ash flow, in the eruption column and in the eruption plume, a few minutes after the eruption. Some ash is fall-out from the plume. Ash and gas are extreme hazards, because they can suffocate all forms of life.

Mud flow is another potential hazard of volcanic eruption, and may be caused by heavy rain on loose ash. Other causes of volcanic hazards include tsunamis, which are caused by underwater volcanic eruptions or by volcanic landslide into the sea. In addition, volcanic eruption may cause earthquakes. If it is an explosive eruption, with granitic lava for example, then a strong earthquake might be expected.

.4. Volcanism at ocean ridges

Basaltic lava erupts at ocean ridges, which form the upper layer of the oceanic crust. When lava is extruded under water, its surface cools down rapidly, forming a flexible rind, whilst the interior is still molten. In this condition, it looks like a stack of pillows, for which reason, it is called "pillow lava".

If lava erupts quickly enough at a hot spot or divergent plate boundary, it may form a sheet flow. In fact, underwater explosive eruptions are unclear, as the pressure is immense in deep water and inhibits the escape of gases. The stress of divergent plates is very powerful. It always pushes a newly-formed oceanic plate towards a convergent plate boundary. When the lava has been pushed to the continental margin, the oceanic crust dives into the continental crust again, then circulates and comes out at the middle ocean ridge as newly-formed lava.

5. Predicting eruptions

About sixty volcanoes are active each year, but less than one tenth erupt seriously. Most eruptions are over within a day, but in a few cases, go on for one year. The average duration is about seven weeks.

One effective means of predicting an eruption is to review previous eruptions. This is good in the case of volcanoes which erupt every few years, because there should be many reports and records available. But if a volcano erupts less frequently, it is very difficult to anticipate the eruption. In this case, we must depend largely on traditional geological skills, especially on the interpretation of past events based on the geological map showing ancient deposits. Additionally, a digital probe and other modern technology can detect the internal pressure inside a volcano, and usually before the main eruption occurs. Some earthquakes occur in advance and the smoke becomes thicker.

Other techniques include measuring changes in the rate of gas emission and gas composition, and monitoring changes in surface temperature. If these precursor signs are fully recognized, they can give days or even months of warning. An accurate warning to within a day is still impossible at present.

2.4.2 Earthquakes

1. How earthquakes happen

There are thousands of geological faults on the Earth's crust. These faults separate at least two areas of crust moving relative to one another. Usually, the movements are only measured in millimeters per year; however, if the movement increases in speed, causing the ground to shake, this is an earthquake event.

The fault sliding is related to plate tectonics. Earthquake zones are manifestations of the phenomenon known as plate tectonics. Plate tectonics is a term describing the manner in which the lithosphere moves around. Most plates contain both continental and oceanic crust, and each plate is in contact with its neighbours on all sides. When plates are moving, the weak points of the crust (faults) are seriously affected, causing the ground to shake and wave until the new position of all plates reaches a new balance.

2. Measuring earthquakes

The most popular means of measuring earthquake intensity is by a number on the Richter scale, which is meant to describe how strong the seismic waves are at the epicenter. The Richter scale can be calculated using signals detected by a single seismometer, when the distance between the epicenter and the measurement point is known, or by comparing data collected from different seismometers at different places. The Richter scale increases by geometrical ratios, mainly measuring seismic energy, and is usually on a scale from 1 to 8. Scale 4 is ten times stronger than scale 3; scale 5 is a hundred times stronger than scale 3 and scale 6 is a thousand times stronger than scale 3.

An alternative to the Richter scale is the Mercalli scale, which is measured according to the severity of earthquake effects; the higher rank on the scale is closer to the epicenter. The Mercalli scale has 12 ranks; rank 1 is the weakest level. The more intense earthquakes are categorized by structural damage, and less intense earthquakes are categorized by effects perceived by people on the spot.

However, buildings are of various designs, and people's observations are subjective. Nowadays, the Richter scale seems more widely used than the Mercalli scale.

3. Earthquake preparedness

There are several ways to make buildings earthquake resistant; this is not just a question of strength; the design of buildings must ensure that when a structure is rocked by an earthquake, every component of the building should sway in the same direction, or it may collapse. Secondly, it is also very important to ensure that buildings can sustain any twisting motion caused by earthquakes, and it is of great help to dig extra-deep foundations resting on solid bedrock.

For most people, there are at least 5 actions to be taken:

(a) If you are indoors, get down or drop down on the floor, take cover under a table or other furniture, or if it is possible, get down and stay between two tables. If the door is nearby, keep the door open. Try to hold the table and move with it if necessary. Stay in position until the earthquake has ceased. Keep away from windows, fireplaces and heavy furniture. Do not rush outside, because any falling glass or building part could be a hazard.

(b) If you are outdoors, stay in an open place, away from any buildings and power lines.

(c) If you are driving, stop and stay inside the vehicle, but not near buildings, trees, lamp posts, electric cables and traffic signs or in tunnels.

(d) If you are in a mountainous area, be aware of falling rocks and mud flow, and keep away from steep slopes.
(e) In a crowded place, do not rush for the exits and try to encourage others to keep calm.

4. Prediction and prevention
It is very difficult to predict earthquakes. Nowadays, earthquake detection is around one minute by seismometer, but accuracy is poor. One of the most effective ways of predicting earthquakes is to map out areas where earthquakes have not been happening recently, but where an identified fault on any side may indicate new epicenters. Then it is possible that a huge amount of stress has built up and is likely to be released soon by a main break up, causing a strong earthquake.
Another suggestion is to observe unusual reactions by animals. It is hard to say which animals are the most sensitive or which can provide longer warning time, but animals that live underground might be the best predictors. There are two possible reasons for this; firstly, their underground senses may be finely tuned, in particular, they might be able to hear some ultrasonic or infrasonic waves caused by geological movements. Some animals are rarely seen above ground, such as moles and earthworms, so that if moles or earthworms are sighted, this can be an indicator of imminent hazard.

5. Undersea earthquakes/Tidal waves
Earthquakes in the ocean usually cause a tsunami (or tidal wave). In most cases, the epicenter is below the sea-floor. In deep water, this wave may not be powerful, but, when it passes to shallow water, the wave behaves like an extremely powerful tide. It may break upon the shore with tremendous force, sweeping buildings and people several tens of meters into the air. To conclude, ground shaking is the major way that seismic waves are transmitted on land, and a tsunami is the main way in which seismic waves travel in the sea. However, a tsunami can also be triggered by landslides or undersea volcanic eruptions.

2.5 Children's understandings related to Earth science.

Section 2.4 has described the accepted views of volcanoes and earthquakes. This section considers existing research into relevant concepts, that might inform my research.

2.5.1 Children's specific understandings related to the internal structure of the Earth

Research by Lillo (1994) in Spain revealed that, when 11-to 15-year-old children were asked to draw a cross-section of the Earth, many depicted a hot melted centre from which magma flowed out to volcanoes on the surface. In the real world, virtually all magma is thought to originate in the upper portion of the mantle or crust. In a small-scale study by Sharp et al (1995) relating to children's conceptions of the Earth's internal structure, it appeared that 9- to 10-year-olds were divided as to whether the earth was hotter or colder at the centre. Some children suggested that it was colder at the centre because the sun's rays could not warm it up. Another idea was that cold water in the sea seeped into the ground and lowered the temperatures. Students also believed that the centre of the Earth was colder in winter than in summer. These results seem to suggest that pupils experience important difficulties with concepts which are not possible to observe.

The Earth's internal structure cannot be observed directly by students. From Lillo's (1994) research data, it can be seen that, although, generally, the students indicate that they believe that the Earth has a concentrically layered structure, this is more clearly defined in the sixth grade than in the fifth grade. Within the same grade, notable differences are found between schools. Very few students believe (as far as one can see from their drawings that appeared in Lillo's research data) there to be layers which are not concentric, and there is considerable agreement with respect to unusual or curious interpretations, such as the belief that there is physically a solid magnet in the centre of the Earth, whereas in fact magnetic forces are present but not the solid metal.

Lillo (1994) found it important to draw attention to designation by pupils of internal compartments in the Earth, with water, lava or gases located in separate areas. Cities might also constitute a compartment, according to some children. They may be influenced by fictional novels and television programmes, even up to Years 5 and 6 (ages 10-12).

From the results of Lillo's study, it seems that a confusion exists about the internal structure of the Earth with concepts of parallels and meridians, as can be seen in the drawings of students. Some students believe that the Earth is a uniform mass - an idea that still persists two to three years later in some eighth grade students. Furthermore, from the study, it can be seen that, by the ages of 13-15 (seventh - eighth grades), the idea that the Earth has a concentric zonal structure is very clear and is represented in a variety of valid ways. In some cases, however, the idea that the volcanic lava comes from the center of the Earth still persists, and therefore the concept is that the nucleus of the Earth is magmatic, and consists of rock melted at high temperatures. Curiously some students suppose that gases are found in the nucleus.

There are roughly six conclusions Lillo comes to from his research, which are:

- Most students considered the division of the Earth's interior to be in concentric layers, and this idea is strengthened between the ages of 13 and 15.
- Most students draw a two-dimensional model and limit the zonation to three shells: crust, mantle and core. Towards the seventh and eighth grades they differentiate between the subdivisions of the mantle and core.
- To remedy the curious answers cited requires individual teaching or perhaps the use of a debating strategy with a group of students so that the contradictory nature of their ideas may be made clear.
- The image of a molten center of the Earth, as the source of the magma which flows out of volcanoes, is persistent. This idea has also been recognized to exist in high school students in Spain by Granda (1988).
- The influence of images seen in films is more persistent amongst 10-12 year olds than in 13-15 year olds.
- Conceptual overload can be recognized in the illustrations of textbooks that students tried to reproduce without possessing the mature spatial perception required to understand them. Most students have failed to complete the three-dimensional diagrams which they set out to draw and annotate.

Ross and Shuell (1993) determined from ninety-one American kindergarten children to sixth graders that, although children associated earthquakes with shaking and trembling and the destruction of buildings, or the splitting open and cracking of the Earth, most could not describe any causal mechanisms other than through a casual association with volcanoes. A few older children did mention plates but their ideas about plates were not followed up. Here, as I have already mentioned, children may have only partial or fragmentary understanding of some concepts, this relates to Happs' (1982 a) study, in which he cites an interesting association between earthquakes and volcanoes by secondary aged children from New Zealand, some suggesting that mountains could become volcanoes if shaken by earthquakes, while peaks with snow on could not. Mountains themselves are often thought by some young children to have been made by "God" or "Man" out of "stones or dirt". Russell et al (1993) determined that infants and juniors had a poor knowledge of the Earth's internal structure, but it did improve with instruction.

In Sharp's (1995) study, the question worded "What is inside the Earth?", proved to be an unfortunate but nevertheless instructive question, resulting, unsurprisingly, in responses such as "tarmac", "bricks", "skeletons", "pipes", "old stuff", "dead plants" and "centipedes". Sharp found that by modifying the question appropriately, however, he was able to establish that the sample group thought that the earth was completely solid and uniform throughout. From the research, it seems that most children held the view that the Earth's interior would also be dark, e.g. "It will be dark because there is no electricity." "Underground it is dark because no sunshine gets in."

None of the children in Sharp's (1995) study had any idea of continental movements (plate tectonics) or had heard of the word plate used in this context. It seems in Sharp's research; many students believe that plates are, after all, "what you get your dinner on" (It seems that the only meaning of plates is dishes). Most of the children seemed happy to accept that, at some time in the past, the distribution of land masses might have been very different to how they appear today, although their accounts of events varied: "When the land breaks up, one side of the land pushes so hard that it makes the other side of the land suddenly let go." "A plate explosion moved them and they floated on water." "Plates are still moving because earthquakes still exist."

Sharp concluded that children's explanations and accounts of natural phenomena, familiar or abstract, differ sharply from currently accepted scientific views. In some instances, the children appeared to have been sufficiently challenged to consider the new information presented to them and their own interpretation of it. In one case, concerning plates and plate movements, for example, it was said that: "Water may split them apart. Floating can't work because you would feel them move." From the above research results, it is clear that some students who believe they understand certain geological phenomenon might not realise that their understanding could be a mis-concept or a misunderstanding, particularly when certain terms are not only used in geological field (e.g. plates could be meaning continental plate or a dish).

2.5.2 Children's specific understandings related to earthquakes

Children have some difficulties in explaining phenomena or misunderstand the principle of Earth science. Ross and Shuell (1993) revealed that, although 11-year-old children appeared to have little difficulty explaining that an earthquake was a shaking of the ground, many could not explain why it occurred. A few suggested that an earthquake happened when the core and the crust collided, but none was able to explain that it was a consequence of plate movement. Leather (1987) found that almost half of 11- to 14-year-olds in his study thought that earthquakes occurred in hot countries, many suggesting that the dry climate caused the Earth's surface to crack. However, beyond the age of 14 there was a sharp decline in this alternative conception, and many instead related the activity to movement along plate and fault boundaries.

A number of researchers have remarked on the inclination for pupils to confuse earthquake with volcanic activity. A good example is Sharp's (1995) finding that some children thought an earthquake occurred when a volcano became hot and shook the ground. Happs (1982 b), in a study of 11-to 17-year-olds knowledge of mountains in New Zealand, found that some students believed that mountains could become volcanoes, if shaken by earthquakes.

The above alternative conceptions might be generated when learners cannot clearly identify overlapping concepts. However, alternative conceptions have been found in students' understanding of where volcanoes occur as well, and concerning the origin of the magma.

Children's ideas about earthquakes might be complex and sometimes mixed up with other geological phenomena. For example, Ault (1985) in the USA found that children's misconceptions about bedrock interfered with their ability to make inferences about the sequence of past events from layered rock exposures. Bezzi (1989) in Italy found that one third of the secondary students interviewed in one seismic province in Italy related earthquakes to the occurrence of volcanoes. Even mature students have some misconceptions about earthquakes; Turner (1984) in USA interviewed 1,450 adults in southern California and found that many believed in such predictors as "earthquake weather".

In Ross & Shuell's (1993) study (USA), approximately two third's of students responded that an earthquake is a shaking/trembling of the Earth or ground. However, categories that seemed to be the result of earthquakes - property damage (to buildings, bridges, and building contents) and injury and death - as opposed to a proper definition of one, emerged in the responses given by fourth, fifth, and sixth graders in the research. One sixth grader answered a question by saying that earthquakes "destroy things," while one first grader responded that buildings fall. Fifteen percent of K-3 students answered that they did not know what an earthquake was, a response not given by any of the fourth to sixth graders. Ross & Shuell (1993) also indicated that idiosyncratic responses worth noting include those of a fourth grader, who defined an earthquake as "a disaster" and then proceeded to note that when it occurs "the ground cracks and it's kind of like a tornado"; a sixth grader who defined an earthquake as "God's way of getting rid of things that aren't supposed to be there"; and another sixth grader said it is an "interruption". It is sometimes difficult to sort out misconception from linguistic lack of competence. In this study, at least one student used the word eruption indiscriminately in a comparative description of an earthquake and a volcano. For example, "when a volcano erupts, it blows out lava, and when an earthquake erupts, it like splits apart" and "An earthquake is something that erupts, moves the world and a volcano is something that erupts with lava". Some students defined a volcano or an earthquake in relation to the presence or absence of a particular attribute: "An earthquake shakes while a volcano doesn't and "In a volcano, lava comes out while in an earthquake it doesn't".

Sharp (1995) also indicated that considering particular earthquakes proved effective, such as the major incidents that had taken place in India and the United States. Although three children expressed some uncertainty with the concept, most associated the word with a cracking or splitting of the ground, events which could last anything from "10 seconds" to "1 week". Other comments included the following:

"It happens by earth movements, it crashes and shakes... the land cracks very deep...they keep happening in the same place."

"They happen in hot countries, it gets hot and the earth cracks. You get some here but you can't feel them because it is not hot here."

"Earthquakes are caused by heat from inside the Earth."

"An earthquake is where a volcano erupts, the ground cracks up because the sun is really hot."

"When a volcano gets really hot it shakes the land and causes earthquake."

"God gets really angry."

Some responses indicated confusion with other types of earth movement and processes:

"Earthquakes are where rocks move, the rocks are loose so that way it happens. There are lots of earthquakes near beaches where rocks fall down."

From Ross & Shuell's (1993) study, the cause of an earthquake seemed difficult for some of the students to identify. For example, there were students in the study that answered they did not know what caused an earthquake, the largest percentage (75%) being the key stage 3 group in his study. Students who were in fourth to sixth grade listed faults as a cause of earthquakes, while the "core" was given as a causal factor only by some of the students. One student noted that an earthquake was "Caused by faults when the core and crust hit each other" (grade 6) and another student said that, "It's when the core gets too hot and hits the surface" (grade 4). Plate movement was given as an answer only at the end of the research. Idiosyncratic answers include heat from the sun on the earth, the earth letting out air like when we cough or sneeze, thunder and rain, wind and mountains.

In Ross & Shuell's study, in response to some questions phrased, "What happens when there is an earthquake? Above ground? Underground?" approximately 40% of the K-3 students replied that they did not know what happened in an earthquake above or below the ground, although no student in grades 4-6 answered in this way. Answers provided by some of the students in this study suggested that the use of phrase "above ground" may have influenced them to mention something in the air. For example, one fifth grader said, "It would get darker or foggy" while a sixth grader answered that things would be "whirling around". Consequently, in this study, these questions were rephrased, so that students were asked what happens "on the ground". This again shows the importance of language in conceptualisation.

It is interesting to see from students' answers that, although students may have different reactions, generally speaking, the reactions can be divided into two broad groups: the most frequent answer in the study, given by 64% of the group, was that the ground would either crack, split, divide or open. The second most frequent answer in the study, given by 35% of the students, was property damage.

Some responses were given exclusively by students in a particular grade, although these differences are probably not grade related. In Ross & Shell's study, only fourth graders mentioned buildings falling down, while only fifth graders noted faults and buildings being swallowed. Two fifth graders mentioned variation in on-ground consequences depending upon the severity of the earthquake, e.g., "In some parts maybe a big hole might form; others might be like cracks in the sidewalk." One fourth grader compared an earthquake to a hurricane, while one sixth grader mentioned the possibility of a tsunami.

When asked about what happens below the surface when there is an earthquake, students' answers varied, and they are difficult to classify into groups. Answers provided by the students included: "Things pop that are underground that are not usually over ground, maybe roots" (grade 2); "Might make the plants screw up because the seeds jiggle around" (grade 3); "Probably rocks would push upward and form rocks like igneous" (grade 4); "Everything turns really hard" (grade 5); and "The core and crust hit each other" (grade 6).

Another sixth grade student noted that the "Earth just has so much energy it needs to get rid of it, just like when we have too much energy we need to get rid of it."

When students were asked about earthquake experience and what to do during an earthquake, interestingly, different age groups gave different answers, but children of the same age group seemed to have more in common. In Ross & Shuell's study; the percentage of students who had experienced an earthquake was 39%. The students who had been in an earthquake indicated that it was small and that there was minimal damage. Two of the students who had experienced an earthquake initially answered "No" but then told about being in a tremor or feeling the floor shake. A fourth-grade student, who said that he had experienced a tremor -as opposed to an earthquake- defined an earthquake as, "Something when the ground splits open and buildings fall down and bridges; they all collapse." When students were asked what to do during an earthquake, only students in the K-3 group answered "I don't know." This was the most frequently given answer for this group, in contrast to the grade 4-6 students in the study, who were most likely to answer that they would go to the basement when an earthquake happened. No student responded that one should get under a desk/table, and less than one quarter replied that one should stand in a doorway. One of the students who responded "stand in a doorway" had experienced an earthquake.
Idiosyncratic responses included: "Try to get the whole family to hold the pet cages" (Grade 2); "Go down to a place where they study earthquakes and tell them what's happening" (Grade 4); "Take a plane anywhere" (Grade 4); and "Hold on to sink pipes in the bathroom" (grade 5). Metal was mentioned several times; for example, a second grader answered that during the earthquake a person should hold onto metal because it is sturdy, and 40% of the fourth graders who answered "stand in a doorway" specifically mentioned metal. Further probing of the latter response resulted in one fourth grader stating, "An earthquake doesn't do metal, it does concrete," an apparent reference to damaged concrete structures seen in the aftermath of the Loma Prieta earthquake.

In this study, a fifth grader who had indicated he would get under a table or in a doorway in the event of an earthquake said that in the "big one", "You would probably want to get outside and stay away from things that would fall. In the 'big one', a doorway would probably fall, too." A sixth-grade student in the same study indicated that, because all

disasters were presented together in the curriculum, she always got things confused and could never figure out what you do for each disaster.
Callister & Mayer (1988) noted that the cause of an earthquake proved to be a difficult question, with some students in the USA indicating they did not know the cause; no student gave plate movement as a cause of earthquakes, less than 10% (only fifth graders who had attended an earthquake presentation the previous year) gave the answer, other answers given by students including faults, earth movement, and heat. Even students who reported that they had experienced an earthquake gave answers to other questions similar to those given by other students. The experience did not guarantee scientific knowledge nor appropriate action.

With Ault (1985), Bezzi (1989), Tuner (1984), Ross & Shuell (1993), Sharp (1995), and Callister et al (1988); the locations for their research were all in earthquake zones in the USA, Asia and Italy, from America, Europe to Asia. It seems that students who live in these earthquake zones have much of a common sense about what an earthquake is and how it feels. Although the students might not fully understand the theories of all earthquake events, however, some indication from the above researches indicates that personal experience of geological events should be one of the main factors that influence pupils' knowledge and personal feelings, and the younger pupils might confuse two similar terms which might sound the same but they are different matters; the older pupils might understand different concepts or phenomena but might not find out the connection in between.

2.6 Students' potential interests as a trigger for learning.

I need to introduce the syllabus, school textbooks and students' potential interests as a trigger for learning, as these are important sources and have a direct bearing on their conceptual development subsequent to "first contact" at home, amongst peers or though the media. This section focuses on pupils' interests.

It is difficult to draw together information on students' potential interests, for the simple reason that school-age children's behaviours are so diverse, regionally and across age-groups. Students, as will be further explained in section 4.2.4 (c), may develop a personal interest in phenomena such as earthquakes as a result of experiencing one.

The word "interest" implies a curiosity or desire to learn more. Generally, across a nation, there might be mixed feelings among schoolchildren about whether or not their schooling is interesting. Certain subjects may arouse more curiosity than others.
One way to promote interest in science is through extra-curricular activities, such as workshop projects (Moore-Hart, 2002) and science fairs (Blenis, 2000). Students in Taiwan are fortunate to be able to go on trips, visit museums, look at models of volcanoes and experience earthquake in simulators. Good teachers provide the motivation for students to develop their interests.

Ideas about promoting science can be collected partly from the literature and partly from experience. Modern classroom methods are about participation, interaction, exploration, investigation, questioning, discussion and project work (Moore-Hart, 2002; Blenis, 2000); teachers must be well-trained in these methods, and schools must create the right environment for effective study.

Koszalka (2001) has highlighted the use of the internet, both in the classroom and at home, as an increasingly useful and used tool of research. According to Moore-Hart (2002), "...writing helps students to better understand science concepts, as it helps them to organize, clarify, synthesize, analyze and integrate their existing knowledge with new concepts." Moore-Hart also indicate that school trips are also a good stimulus, Moore-Hart cited that outside school hours, parents must try to ensure that their children have a balanced, healthy life, perhaps also with family visits to places of scientific interest.

Personal interest could be also trigged by the syllabus or science and Earth science textbooks, which must be well-written and presented to attract students' attention. The syllabus and textbook content should show the relation to knowledge between Earth science and geo-science. This is helpful to the understanding of what kind of basic scientific ideas about earthquakes and volcanic events studenys might have, or even just to understand what kind of relevant concepts have been introduced. Secondly, by reviewing the syllabus and textbooks, I can survey how the educational committee attempts to build Earth science knowledge from primary level to senior level through their general science and Earth science textbooks. Modifications to textbooks over the year groups should reflect the students progression in knowledge in the Earth science field. That is why it is necessary to review it here.

There are in total 12 volumes of science textbooks and 12 science practice books for primary school students in Taiwan. The science teaching areas include Earth Science, Chemistry, Physics and Ecology. I will focus only on the parts of textbooks on Earth Science, which I classify into two styles, the "indirect" and the "direct". The indirect type introduces Earth science or geo-science concepts through other topics; this happens more in the lower grades (Year 1 and Year 2) rather than in the middle grades. These 2 styles alternate through Books 1-12, each year covering two books. (Books1&2 used by Year 1, Books 3&4 used by Year 2, Books 5&6 used by Year 3, Books 7&8 used by Year 4, Books 9&10 used by Year 5, Books 11&12 used by Year 6).

The texts give me a basic idea of the knowledge students should have of earthquakes/volcanoes and students' potential interests as a trigger for learning, and throw into relief the status of their actual understanding. This relates to my research questions 1 and 2. (1.How much knowledge do students have about earthquakes/volcanoes and related events, and what is the status of their understanding of the phenomena? 2. What are the students' ideas concerning the relationship between earthquakes and volcanic events?) Certainly, students might not receive all of their knowledge from school textbooks, but I can find out what kinds of concepts are expected to be introduced to students and then compare with what they appear to know from the interviews and from their drawings.

2.6.1 The principle of analyzing scientific textbooks

I divide scientific text into two parts; one is the scientific text directly related to earth science and the other one is indirect. One part of the text explains scientific concepts related to Earth science or geo-science, the other part explains other concepts (i.e. it does not related directly to Earth science). In order to give an idea of the distribution of key concepts in texts, I identified the specific concepts being explained (e.g. fossils: geo-science concept; oceanic and environmental protection: Earth science concept; how to

treasure natural resources: indirect Earth science concepts). The proportions of concepts in relation to geo-science or Earth science can then be calculated.
The reason that I classified scientific text this way is because it is clearer to work out in which stage or which section/chapter there is relevant learning material refering to volcanic and earthquake events. It is helpful particularly in Primary level as I mentioned earlier; because there is only general science textbooks used in Primary level, therefore, the relevant texts are placed among each scientific textbook. However, in Junior and Senior level, earth science is an individual and professional subject, and the text relating to volcanic and earthquake events are more complete and systematic. Hence, for the purpose of comparing the relevant text systematically throughout Primary and Secondary level, a unified comparative model is necessary. Therefore, identifying relevant text and classify it into direct and indirect style is a systematic and simple method of categorizing textbook material. In addition, the text is categorized to show the major concepts relating to earthquakes, volcanoes and the age at which they are introduced and developed.

2.6.2 Earth science and geo-science study text in Indirect Style

The textbook material described below is not presented in chronological order by each chapter (e.g. Chapter 9-1 first, then Chapter 7-1, and back to Chapter 11-5), however, it is presented in chronological order by each volume of textbook (e.g. Book 9 first, then Book 10). The reason for not using chronological order by each chapter is to enable a coherent introduction of different geological concepts throughout whole scientific text.

In Book 9, Chapter 1 (9-1), "Sun observation", Year 5 students learn how to describe and identify geo-scenery using 8 directions (East, West, North, South, Northwest, Northeast, Southwest, Southeast), thus establishing the basics of map reading for the coming study of map making. Although this chapter contains several ideas from 7-1 ("Moon Observation"), these have only limited relevance to my topic. This chapter will connect with 11-5 ("Day-Night and four seasons"), and again, there are few ideas related to my topic there.

Book 10, Chapter 6 (10-6), "The weather in Taiwan" introduces the position of Taiwan on the world's map, and describes how the weather is affected by the terrain in Taiwan. The teacher's handbook also remarks on the geo-science of the polar regions of the Earth, the equator, desert and oceanfront. I believe that students can learn a number of related concepts from this unit: on Earth for example, different topographies (for example, oceanfront, desert and grassland) give rise to different air-masses with different characteristics, causing different weather and climate, and, therefore differing geo-science features. An important focus in this part of the textbook is geo-disaster. Most geo-disasters in Taiwan are caused by typhoon; hence, disaster areas are clearly identified in photographs. This chapter takes up the foundations from 5-4 ("Weather observation"), but includes more causes of land-formation and terrain. This chapter also connects with 12-3 "Our family--Earth".

Book 12, Chapter 1 (12-1,"Our living environment") and Chapter 2 (12-2,"Discussion of environmental problems") introduce Earth's environment and contemporary environmental issues. It is my opinion that students should be taught a number of aspects of soil function, with emphasis on how soil retains water and the impacts when soil is no longer able to perform its function because of urban development. Soil erosion is another issue. Such understanding can help students to appreciate that soil is not only a medium for growing plants, but also plays other important environmental roles.

2.6.3 Earth science and Geo-science study text in Direct Style

Book 6, Chapter 6 (6-6,"The Power of Water Current") gives students an understanding of the power from water current so that students may realize that currents have the power of erosion, movement and sedimentation. This kind of power is a main cause of change on the Earth's surface. This chapter and 4-5 ("Soil and Sand") are related, but it introduces more about how and why the terrain changes, and talks about the formation of groundwater, which could be the foundation for 7-5 ("Water") as well.

Book 10, Chapter 7 ("The land around us") demonstrates how sand and soil from rivers eventually precipitate as a geological layer (Earth Science) in the ocean and indicates how Earth contains many resources, including rocks and minerals, with their several characteristics for identification. This chapter encourages students to observe the land around us and asks them to guess how geological layers are formed and why the layers become curved as well. The following stage is to lead pupils to realize that natural resources are all limited around our world. This chapter builds on 4-5 ("Soil and Sand") and 6-6 ("The Power of Water Current"). In 12-3 ("Our family—earth") first of all introduces the Earth's environment, which includes the lithosphere, atmosphere and hydromosphere.

In the final chapter Book 12, Chapter 4 (12-4), the main focus is on Earth's resources. Students are encouraged to treasure our limited resources, with a good example being forest reserves; if we keep destroying the forest, our later generations may not have this Earth resource forever. This chapter draws together all the concepts and skills of the past 6 years and tries to train students in an attitude of problem solving. It may be noted from the above that earthquakes have not been referred to.

2.6.4 Earth science and Geo-science Study text in Junior High School

Junior level textbooks have been in use in Taiwanese schools for a long time. There is only one textbook in which Year 9 (Junior Year 3) students start to learn Earth Science. The two main aims of this text are to introduce fundamental concepts in Earth Science Study and to develop the abilities of problem solving in students.

At junior level, the Earth Science courses are more specific than at primary level, and, the concepts of Topography and Geo-scenery are more abundant. 37.7% (The sum of concepts directly concerned with Topography and Geo-scenery divided by the sum of whole geological concepts in the textbook, and then multiplied by 100%=37.7%) of the textbooks are directly concerned with Topography and Geo-scenery, which is more than one-third of the whole text. Other parts refer to Topography and Geo-scenery in an indirect way. For every main question posed to the student, the key concept for that question was identified as the type and number of concepts was determined by examining the questions posed to the student in the text.

At the beginning of each chapter, there is a foreword to introduce what is the main purpose or topic of the chapter as a whole, and then each section generally focuses on one or two items of conceptual knowledge. At the end of each section, there are several practice sections relating to learning and, as I see it, these practice sections have a dual purpose, serving not only to help students to revise the key concepts, but also to stimulate students to note the local environment and to apply the scientific knowledge and understanding they have gained.

There are a total of 7 chapters; but for the purpose of analysis I select and divide the chapter sections into four groups:

Table 2.1 Group 1 Astronomy and Atmosphere

Chapter/Section	Heading
1-1	The history of the universe
1-2	The history of the solar system
5-1	The atmosphere
5-2	Ozone and vapour
6-1	Weather change
6-2	The weather in Taiwan

Table 2.2 Group 2 Geological Movements and Earth science

Chapter/Section	Heading
1-3	The evolution and formation of the Earth
2-1	Plate tectonics
2-2	Mountain movement, volcanoes and earthquakes
3-1	The formation of mountains and rivers

Table 2.3 Group 3 Geo-science and Aqua-effects

Chapter/Section	Heading
3-1	The formation of river beds
3-2	The balance of riverbeds
3-3	The balance of coastlines
3-4	Rivers and mountains in Taiwan
3-5	Landslip and floods
4-1	Water distribution and cycles
4-2	Ground water
4-3	The maritime space around Taiwan
4-4	Oceanic environmental protection

Table 2.4 Group 4 Paleontology and Earth's Natural Resources

Chapter/Section	Heading
1-4	The evolution of life
7-1	Stratum history
7-2	Fossils
7-3	Natural resources
7-4	How to treasure natural resources

Table 2.5 The proportion of Earth science and Geo-science concepts at junior level

Topics	Proportion (%)
Earth science	40.5%
Geo-science	59.5%

2.6.5 Earth science and Geo-science study textbooks in Senior High School

At senior level, students should understand how volcanoes act and the connection between magma and volcanic activity. Students are taught to identify the physical characteristics of minerals, including: colour, streaks, luster, hardness, specific gravity and other features. I believe that these are a great help for students in identifying general volcanic characteristics. In fact, this is very useful knowledge for students, because, in Taiwan, volcanoes in the north and south have had a different formation process. Hence, if students can identify the different volcanic characteristics using mineral reference as well, this will be a good link between theoretical and practical learning.

In this stage, students are to understand that earthquakes may be caused by a variety of reasons, such as orogenesis and plate tectonics. Moreover, students should go further in understanding how seismic waves occur and how many kinds of seismic waves are generated when an earthquake occurs. The characteristics of seismic waves are another introductory point. At senior level, students are also taught the details of seismic zones, and, in this context, they appreciate earthquakes in Taiwan. Students may understand how many local seismic zones there are in Taiwan, and how to be alert to them.

The relevant chapters on volcano and earthquake knowledge are Chapter 6 (Geological Structure) and Chapter 7 (Crustal Movement) in Book 2. These two chapters are taught in the second year of senior level, where students learn about oceanic volcanoes, and the relationship between earthquakes and faults.

At the beginning of Chapter 7, the textbook leads students to discover evidence of crustal movement by earthquake monitoring. In Chapter 6, the textbook had referred to folds and faults, which also relate to crustal movement. Later, the text indicates a cross-cutting relationship. The main text returns to volcanic activities, especially in the part about non-conformity, which emphasizes how magma intrudes into existing geological layers. With graphical illustration, students should be able to gain a clearer idea of volcanic activities.

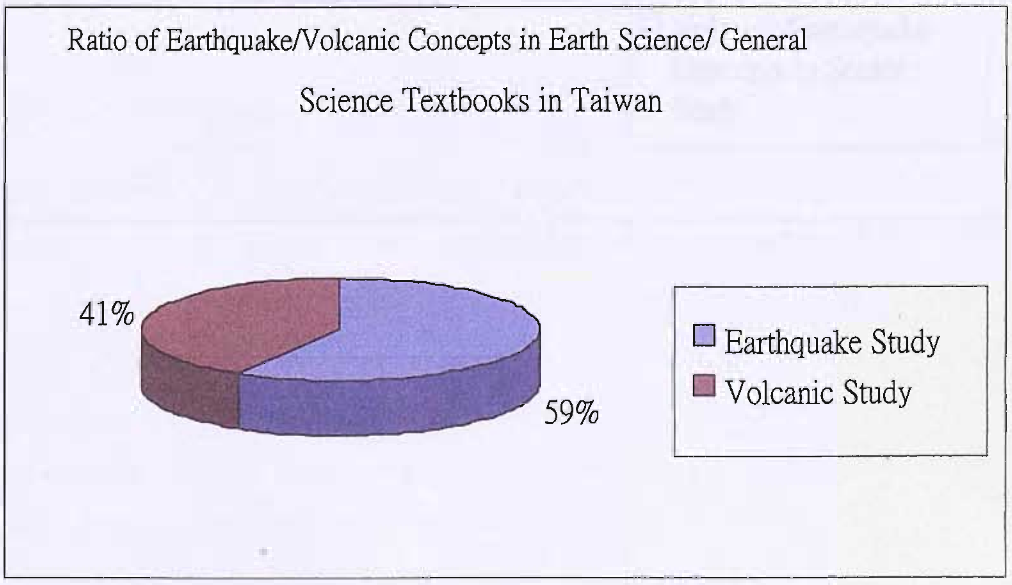
In summary, Books 1 and 2 are the main texts for introducing earthquake and volcanic activities. By the second year of senior high school, pupils should have acquired an intermediate level of understanding of earthquake and volcanic activity, and they should have a good grasp of the following concepts:

Table 2.6 What students are expected to learn about earthquakes and volcanic events from Secondary textbooks (senior high school)

Concepts	**Percentage (%) of material in textbooks**	**Remarks**
Volcanism	22.7%	This has the highest ratio in the textbook
Circum-Pacific earthquakes/volcanic range	4.5%	This has the equal lowest ratio in the textbook
Seismic surveys	4.5%	This has the equal lowest ratio in the textbook
Metamorphism	9.0%	
Fumaroles	4.5%	This has the equal lowest ratio in the textbook
Igneous effects	9.0%	
Internal structure	13.5%	

Taken together, these concepts form a coherent conceptual structure, and as such lay the basis for a coherent understanding of earthquake and volcanic phenomena. Figure 2 below illustrates the distribution of earthquake as against volcano information in Taiwan's textbooks.

Figure 2.1 Ratio of earthquake/volcanic concepts appearing in Earth science/General science textbooks in Taiwan



2.7 Implications for the current research

Earth science education has been a part of the Taiwanese curriculum for more than 10 years. Although in primary school Earth Science is not yet an individual subject as such, nevertheless there are still many geo-concepts distributed through the different chapters of the Science textbook. As Taiwan is located in the Circum-Pacific Earthquake/Volcanic Zone, I would like to focus on the understanding of volcanic and earthquake phenomena in my research, asking questions such as: What are the kinds of wrong (or mythical) concept(s) in pupils' minds? How do the concepts evolve? What are their bases? Why do students agree on or believe in wrong conceptions? And how can we lead students to correct their misconceptions?

Figure 3 below shows the concepts at different school levels as shown in the textbooks.

Figure 2.2 Volcanic/earthquake concepts at different schooling levels

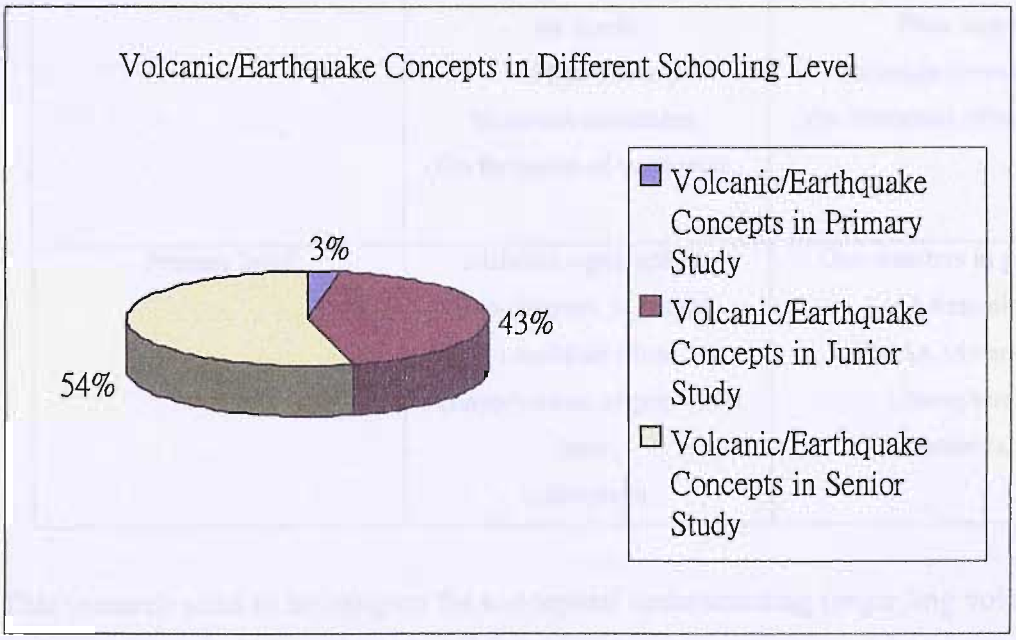


Table 2.7 What students are expected to learn about earthquakes and volcanic events from Primary level to Secondary level

School grade	Earthquake and relevant concepts expected to learn	Volcanic and relevant concepts expected to learn
Senior level	Circum-Pacific Earthquakes/Seismic zone, Seismic waves, Internal Structure, Orogenesis, Plate tectonics, Faults, Crustal movement,	Volcanism, Circum-Pacific Volcanic zone, Metamorphism, Fumarole, Igneous effects, Internal Structure, Seismic surveys, Oceanic volcanoes, Magma, Intrusive movement,
Junior level	Stratum history Fossils The evolution and formation of the Earth, Plate tectonics, Mountain movement, The formation of mountains ,	Natural resources, The evolution and formation of the Earth, Plate tectonics, Mountain movement, The formation of mountains
Primary level	Different topographies, Geo-disasters in general, Land-formation, The movement of geological layer, Lithosphere,	Geo-disasters in general, Land-formation, Rocks, Minerals, Lithosphere, Resources,

This research aims to investigate the conceptual understanding (regarding volcanoes and earthquakes) of students. It is based on the results of existing research. I would like to use my findings to suggest improved teaching methods, or a rearrangement, where desirable, of the order in which concepts are introduced in Earth science textbooks, and in the curriculum. Importantly also, in the case of senior high school students, is the question as to whether they can link/connect Earth science concepts they learned in primary school, through junior high school and senior high school.

I am also looking at student motivation. Are students arriving at a better conceptual understanding of topics in which they are interested?

2.8 Chapter Summary

The literature on children's ideas focused on instances of understanding of earthquakes (research on early primary age to secondary level). The literature on volcanoes is less extensive and specific. Children's ideas on earth science are divided into three parts: internal structure, earth shape and the understanding of geo-phenomena (volcanoes and earthquakes). Many young pupils, especially below junior high level, seem to have no clear ideas or understanding of the topic from the research evidence reviewed.

Children's ideas in Earth Science have given rise to different outcomes and interpretations and these in turn have resulted in different views of their nature and status. Students in junior and primary level have only limited correct ideas about earth science concepts. In the review, it is very difficult to find any research specifically into children's ideas regarding volcanoes. However, this is the key study point in this research. This research is primarily a study of children's ideas concerning both volcanoes and earthquakes. It takes its starting point from the existing findings, but unlike the existing research it is a cross-age study of pupils' ideas from primary to senior level in the Taiwanese school system.

It is hoped that the findings in this research will contribute to our understanding of the processes of knowledge acquisition and concept formation specific to Earth Science, and specific further to the syllabus in Taiwanese schools. It is also hoped, leading on from there, that my findings may prove useful both to teachers and to syllabus and curriculum designers. In the following chapter, therefore, I consider the methodology for my research. Whereas most of the literature I have reviewed reports on research done on the scientific understanding and development of genuine (as opposed to "mythical" or "alternative framework") scientific description and explanation within a generally Western (European, American and Australian) cultural context, my own research is of course in the context of a very different culture. Whilst the research carried out on British, Australian and children of other Western countries is by no means irrelevant to my own purposes, the phenomenon of "situated cognition" (George and Glasgow, 1988) is, likely to have an impact, although it is not clear yet about the difference of earth science learning status between Taiwanese and Western school, but according to Driver (1994), Steffe (1995), Spivey (1997), Larochelle (1998) and Selley's (1999) researches, it seems no matter from which cultural background, students' learning is generally based on constructivist theory but it could be slightly changed according to the different conceptual developments. These research results need to be taken into account, both when I obtain data and in its analysis.

Here, I would like to emphasize the importance of the relationship between the research questions and the literature review, which are:

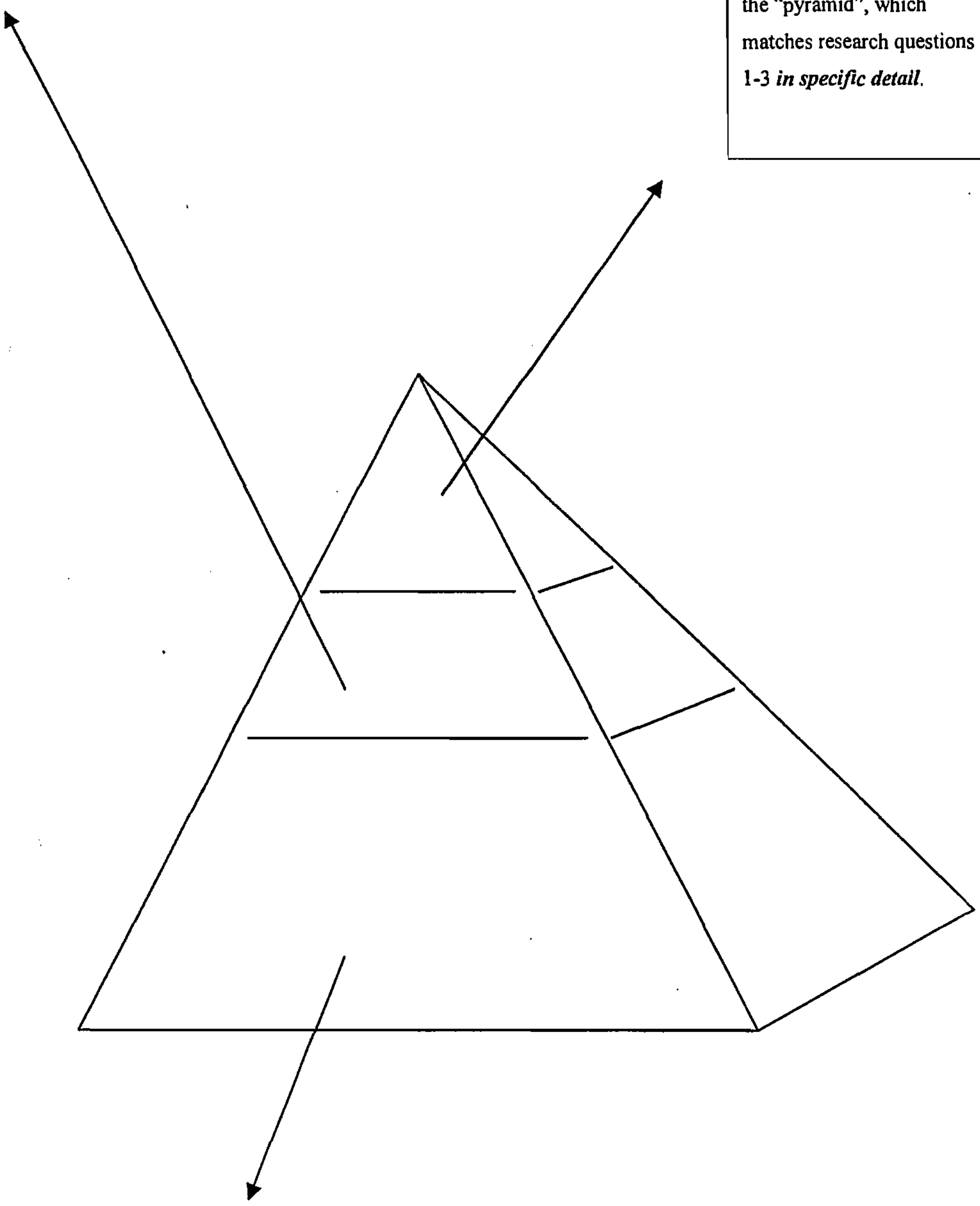
The literature review in this chapter may be modeled as volume of a pyramid. At the ***bottom*** of the pyramid I aimed to see how much knowledge or how many concepts of general science students might already have or understand. In **2.2,** therefore, I looked at research on children's ideas in science which match my research question 1-3. Sections **2.3.1** (Children's ideas in geo-science and Earth science) to **2.3.2.3** (Earthquakes) can be regarded as the ***middle part*** of the "pyramid", which corresponds to my research question 1-3 ***but not in great detail.*** **2.5** (What are the specific understandings related to Earth science in this research) and **2.6** (The Syllabus and text in Taiwan: Implications for teaching and learning) are the ***top part*** of the "pyramid", which matches research questions 1-3 ***in specific detail.***

The pyramid model takes the data collected from research interviews, the findings and comparisons to measure growth and applies ways to further curriculum development in Taiwan; this vital purpose also conforms to the aim of research question 4.

Schematic Diagram of the literature review in the model of pyramid volume

Children's ideas in geo-science, Earth science and Earthquakes can be regarded as the ***middle part*** of the "pyramid", which corresponds to my research question 1-3 ***but not in great detail.***

The specific understandings related to Earth science in this research and the Syllabus are the ***top part*** of the "pyramid", which matches research questions 1-3 ***in specific detail.***



At the ***bottom*** of the pyramid I aimed to see how much knowledge or how many concepts of general science students might already have or understand.

Chapter 3 Research Methods and Pilot Study

3.1 Introduction

This chapter firstly introduces the research methods and discusses the various aspects of the research methodology. Connections between the topics of each chapter and the research questions will be indicated at appropriate sections. The research questions are repeated here, however, to guide the chapter.

1. **How much knowledge do students have about earthquakes/volcanoes and related events, and what is the status of their understanding of the phenomena?**
2. **What are the students' ideas concerning the relationship between earthquakes and volcanic events?**
3. **Have the students own experiences of earthquakes and volcanic events prepared them to know what to do when they happen?**
4. **Can the findings be used in curriculum development in Taiwan?**

A cross-age study fulfils the purpose of the research, namely to seek an understanding of how students' conceptions develop over time. Sampling over a range of ages gives a clearer idea about progression in students' understanding.

This research is designed as a cross-age rather than a longitudinal study. A longitudinal study would require several more years to complete as a case observation. It would be very difficult to have this kind of long term observation completed for 100 students. Besides, during long observation, it is likely that there would be loss of data because it could be difficult to maintain the level of contact with students and their willingness to participate.

As a cross-age study, I can select students for the research sample from different age groups, and these groups of students can cover the same age-range that a longitudinal research study would. The advantage of doing a cross-age study is that I can collect data in a short time period. In undertaking a cross-age study, I try to strike a balance between qualitative research and quantitative methods. I incorporate a qualitative research approach in using interviews and drawings as the major research instruments, for the purpose of micro analysis. By sampling 25 students at each of four ages, the sample size at each age is sufficient also to enable quantitative comparisons between the responses of different ages.

The ages selected for study were chosen for the following reason. Primary school is twice as long as Junior or Senior schools, so it is divided into two. Primary Year 3 (age 8-9) is at the mid-point and Year 6 (age11-12) is at the end; Junior Year 3 (age14-15) is the end of that school and Senior Year 3 (age17-18) is also the end. These four age groups are evenly spread and constitute a mid-point and end-points.

The research design must take into consideration the following miscellaneous factors: Firstly, the research has a practical connection to students' life, as they may live in potential earthquake zones, and must understand the phenomenon, and know what to do in the event of an occurrence. The data collection methods, interview and drawings, should therefore investigate this area of knowledge. Secondly, the results must reflect the level of students' understanding, which means that the interview questions have to be clearly expressed and understood. Thirdly, the interview must not offer too much help to the students, in order that they are tested properly. For example, no suggestion was made concerning the relationship between earthquakes and volcanic events. The children should be able to give their own opinions without help. Fourthly, the questions should probe the students regarding sequences of actions to be taken in the event of earthquakes or volcanic eruption. Finally, data collection must be as detailed as possible and the sample population must be representative of the different study levels.

The purpose of this research design is to reveal as fully as possible students' understanding of earthquake and volcanic events, students' ideas about the possible link between them and finally knowledge of how to react if or when they occur.

The reasons for this particular study are two:

(a) The relative paucity of research in the area of Earth Science education;
(b) The absence so far as I am aware in the literature of such a study conducted over the age-range that I have chosen.

Regarding the second point, with the range that I have targeted, from 7 or 8 years to 18 years, I hope that analysis of the data might throw interesting light on development from childhood to adolescence in terms of the concepts central to Earth Science. There might be some points of interest regarding the development of conceptual structuring over this crucial span of cognitive/intellectual development, generally, as well as in the context more particularly of the Earth Science curriculum and the learning of the subject.

I also hoped that my study might have some fruitful practical purposes in the development of the Natural Science Curriculum, in awakening students to the importance of understanding Earth Science, and also in raising both students' and teachers' awareness of earthquake/volcanic hazards, measures that can be sensibly taken against the risks and appropriate reactions in the occurrence of earthquake/volcanic phenomena. Taiwan being both prone to earthquakes and home to a number of dormant volcanoes, such an awareness is much needed, in fact, and yet, until now, no systematic or sustained attempt has been made to educate students in this very practical and important area.

Here, I would like to explain the means and processes I use to find out how students think about earthquakes and volcanic events. I also introduce a series of steps (including the interviews and annotated drawings) to provide an orderly arrangement for the study. This chapter then focuses primarily on the principle means by which I hope to elicit pupils' knowledge and understanding of earthquakes and volcanoes.

In this research, the main method is the interview, but annotated drawings/descriptions elicited from students are also a very useful supplement, one of the major advantages is it allowed me to compare the results from both interview and annotated drawings, this comparison can help me to find out pupils' understanding intersects, and help me to confirm what kind of geological concepts that pupils really have. I will discuss the detail of comparison in Chapter 4.

The interactions between interviewer and interviewee are important; in classroom investigation these interactions might affect data collection (consciously or otherwise); so the face to face interview is the best method for this sort of cross-age research.

The strengths of the interview method are that I can gain firsthand feedback immediately, and I can observe students' reactions first-hand. If students' answers are not clear, I can set out another way to clarify their real thoughts. The interview is a good method to find out if the interviewee truly understands the concepts or not. Because the interviews were face-to-face, and one-to-one, as soon as I felt some uncertainty, I was able to employ another question, testing the same concept, to verify what students' real ideas were. Nevertheless, there are some inconveniences to the interview method as well. For example, a full interview needs a lot of time for collecting and arranging the results. This is because, for a complete interview, there are generally multiple questions, each question needing some minutes to deal with it; interviewing one hundred students would take more than 10 days to complete. Secondly, there is much preparation work to be done in advance. Interviewing students in Primary school and Secondary school required the researcher to apply for permission from the school authorities and also to arrange for a proper place for interviewing the students. The difficulty was that the school authorities do not usually want to interrupt the classes for external activities, and this increases the difficulty of applying to do interviews as a research method.

In my research, the above problems (the inconveniences and the difficulty) did occur. Notwithstanding, efficient and accurate feedback from the students, detailed responses and complete data outweighed the difficulties of the study.

3.2 Participants and Location

The 100 students involved in the research comprised 25 students from primary level year 3 (aged 8-9), and 25 students from primary level year 6 (aged 11-12), 25 students from junior high school in year 3 (aged 14-15) and 25 students from senior high school in year 3 (aged 17-18). Detailed rationale and a description of interviews follows in section 3.3.

The research was undertaken in the Great Taipei District in July, 2004; primary and secondary schools in the Great Taipei District (which means Taipei city and Taipei County) are both generally divided into two types. One is private primary or private secondary schools, which usually attract students from wealthy families. Students have to pay double or even triple the tuition fees that students who study in state schools pay. In the private schools, the students can be differentiated into three main levels (based on test, examination and assessment results): top, middle and lower. However, the range of students' abilities (from top to bottom) is usually narrower than in state schools. This is because entrance to most private schools depends on an examination. This examination screens the students whom the schools would like to accept. Student numbers in private schools vary, but, generally speaking, there are around 30 students in each class. The other types of schools in the Great Taipei District are state schools, which are supported by the government. They are open to the whole population and thus represent the majority of students in the area. In the early years of state schools, class sizes were about 50-55 students, but nowadays, there are only around 35 students per class.

For each school level, one average status school only was selected. In each school one class was adopted as being representative. From around 35 students in each class, 25 were chosen as the sample for data collection, 8 were from the top of the class, 9 in the middle, and 8 from the bottom. All selections were made according to the general student score results from different schools, the students' levels were also compared, and appeared to be distributed evenly. This arrangement is termed cluster sampling. According to Cohen et al. (2000), "When the population is large and widely dispersed, gathering a simple random sample poses administrative problems. Suppose we want to survey students' fitness levels in a particularly large community. It would be completely impractical to select students and spend an inordinate amount of time traveling about in order to test them." Accordingly, I felt I should adopt some suitable schools and also use the students for investigation in these adopted schools by cluster sampling. In fact, cluster samples are very suitable and popularly applied in small scale research (Cohen et al, 2000); but if working with a wider population, the researcher should sharpen his sampling, because this can help the researcher to remark on almost every part of the findings. In this study, the range of the sample was wide, from primary level to senior level and the performance level was also spread from low to high.

3.3 Instrumentation

Before I started to collect the data, two research methods were considered, one was one to one interview, the other one was class observation. Both research methods contained interaction directly with the pupils, however, one to one direct contact might give more chance to carry out detail cross-examination to the pupils rather than class observation (Cohen et al, 2000). Therefore, interview is the main research method in this study. Apart from the above consideration, another reason for adopting it was because the interview has immediacy and quick interaction, and these two advantages cannot be replaced by other research methods. Because of these advantages, the researcher could trace students' reactions and even recapitulate on their ideas. During interviews, the procedure for asking can be more flexible than with other methods, and this allowed the researcher to have extra space to adjust or add some further questions for additional purposes. The flexibility also allowed me to reduce/change unnecessary questions.

The reliability in this study was ensured by cross-examination which is verifying pupil's attitudes, opinions, misunderstanding and misconceptions (Cohen, 2000 and Wellington, 2000). The specific way of doing it during the interview is firstly to confirm the same concepts/ideas by asking additional questions, and secondly re-confirm the concept through other established questions if it is related, and finally triple-confirm the concept through pupils' map skills or annotated drawings.

In this study, it was easy to follow a particular track of research or some new topics as they arose; according to Cannell and Kahn (1968) the nature of the interview is "conversation with a purpose", and of course the purpose here was to obtain data. The interviews should not be regarded, however, as a sort of "short cut" for gaining information, but as a direct way of collecting data from informants. The feedback obtainable in the course of an interview is usually more than just information, and can lead to an arrangement of that information, in qualitative and quantitative forms of data analysis and presentation. In this research, there were two evenly distributed kinds of responses. For the first part of questions (General Interview Questions), I designed the interview questions with control of direction in mind, and so the likely range of responses was limited. Here I intended to find out whether or not students had some specific (index) concepts about earthquakes or volcanic events, and therefore, the freedom of range of students' answers was relatively out of the control of students. But in the second part of the interviews (Further Interview Questions), the aim of the research was to find out how deep and broad the students' knowledge of earthquakes and volcanic events was; hence, the questions were more "open"; I expected more answers from students, so the purpose of the question design was not to expect any specific concept, but to understand the limit/maximum of students' knowledge, and hence the students had a chance to give more input to the interview.

Individual or one-to-one interviews avoid interference from other respondents. When students are interviewed together, some weakly held opinions/concepts might be overpowered by the strong/majority opinions/concepts of other students. If they have different or minority concepts/ideas, they may not express them in the presence of others. In this study, the interviews sought what was "at the back of the students' minds", thus supplying an opportunity to the researcher to characterize and appraise what the students were aware of and what the students believed. From the interviews, I could also appreciate some of the relevant experiences that students had had. The research interviews as applied here synthesized many of the characteristics mentioned above, the main point being to obtain complete oral or written information as much as possible.

In addtition to interview questions, annotated drawing was also used to collect pupils' relevant concepts in my research. Each pupil was asked to draw "a volcano" and "earthquakes" individually, I then analysed drawings to examine the understanding shown and compare with interview outcomes. According to Chula (1998), a number of pupils present more concepts through their drawings rather than saying. I compare the similarity and difference from pupils' drawings and their interview results; Lillo (1994) believed that this sort of intersecting comparison can improve the accuracy and reliability of data analysis.

3.3.1 The process of interviewing

According to Wellington (2000), one of the key issues for interviewers is how to draw up the initial interview plan. Furthermore, in order for the interview to be a success, the students must fully realize the meanings of questions, and the information received must be clear and unambiguous. Moreover, the use of language must match the lexical ability and general background of the students. It is not enough for the students to somehow sense the content and meaning of each question according to their own limited and even idiosyncratic preconceptions. Avoiding confusion while the interview is in progress is a key point. This can be achieved by using single ideas/concepts for each question. A battery of such questions is an ideal method to detect students' knowledge and also avoid confusion (Cannell and Kahn, 1968), which might unsettle them. In such a battery, questions can all aim at one target topic at the same time, but each constituent question should contain a single and clear central concept/idea. By this means, the interviewer not only gets a fairly complete picture of a student's understanding in one target topic, but he can also "catch" several important concepts one by one without confusion. This means that questions and tasks should be revised to make sure that no question contains multi-concepts.

In designing my own interviews, therefore, I tried to construct the questioning so that within a given area (e.g. earthquake or volcano), the succession of questions should lead the students thoughtfully through the interview, with the most complex questions coming from the middle to the end. The sequence of topics (e.g. volcanic eruption, volcanic ash, how to deal with earthquakes and the effects of earthquakes) was designed to make the entire interview experience as thoughtful as possible and also to afford wide scope and sensible intention. Transitions from area to area (earthquakes, volcanoes, internal geo-structure, tectonics and the Circum-Pacific Basin system) were eased by way of explanation, qualification or introduction to the new concept, linking it to the topic previously discussed. Of course, some students may not understand the purport of the questions properly. The students may not have had enough background knowledge or necessary information to reply to the question, or alternatively they may have lacked the ability to remember the information requested.

Students sometimes have difficulty in expressing themselves verbally, in which case, drawing or identifying some specific illustration or any other suitable means was accepted. The point was to obtain feedback in the manner they were most comfortable with.

3.3.2 The knowledge and understanding possessed by students

First of all, during the interview process, the researcher has to identify what kinds of knowledge students have acquired regarding earthquakes and volcanoes; and secondly, and more importantly, what is the depth of their understanding. The gap between original knowledge source(s) and subsequent understanding was one of the focuses of the interviews.

As indicated earlier, this study of students' knowledge should importantly determine how students conceptualize earthquakes, volcanic events and other relevant phenomena of Earth Science, which normally means eliciting their knowledge and realizations from them.

Because of these considerations, the interview itself should avoid any suggestions or leading questions. The aim of the interview is to gain insight into the "true status" of students' knowledge, the way they think and the motives leading them to think in this particular way.

Especially when earthquakes and volcanic events relate to everyday life, Ryle (1949) believed that a "common use of language" could be a key point to determine how students think as regards the natural science event. The "common use of language" here means language used in "informal", "casual" conversation, because in most cases young children understand the world in this way. As Ryle (1949) said, this type of knowledge is called "knowing that" knowledge. In this project, this type of knowledge could be expected to exist in most pupils' minds; in fact, in Ryle's studies, knowledge of this type is typically declarative and it is very close to the semantic and episodic context of long-period memory. This sort of memory or knowledge constitutes the students' "natural ideas" being sought. In addition, according to Tulving (1972), semantic memory is highly connected to the memory for words, general knowledge and concepts, and therefore, when the interview questions are designed, these factors should be considered carefully. Tulving (1972) insisted that a clear, easily understandable question should reduce the chance of misunderstanding, and increase the accuracy of results. Moreover, Tulving believed to avoid mis-analysing data, an understanding of students' semantic memory is crucially important.

In addition to verbal questions, the interview schedule also anticipates the preparation of hand-drawing questions. Here, asking students to draw what they think about earthquake and volcanic events is intended to elicit subconscious understanding and make up for the insufficiencies of verbal answers. Sometimes, students may present in this way ideas which have never been taught or presented in any medium or resources.

According to Ogborn (1993), "Being able to do what another does or to say what they have been told is not enough to say that there is understanding". For this very reason, "knowing that" seems clearly not enough for a researcher to understand a student's true ideas. To gauge a student's understanding, a researcher should probe further, proceeding to "knowing why" questions when necessary.

Thus the interview schedule was designed to move from questions which explored description to those which explored explanations.

3.3.3 The links between the interview schedule and students' concepts

In drawing up the interview schedule, the ordering of the questions was modified after piloting in order to best investigate the processes at work in the formation of students' concepts, their acquisition of new concepts and the integration of those with existing, already held concepts. Of course, the above three factors have no absolute order, especially as, quite often, an existing concept or complex of concepts will be modified, or even quite radically altered as a result of new concept formation. The order and text of the interview questions was intended to throw light on the schema of students' ideas. Bruner (1956) believes that a schema can be regarded as an organizing structure for knowledge, and a schema may be regarded as one of many distinct types when describing unlike groups of knowledge.

In this research project, it has been thought best to adopt pupils' "declarative" knowledge (to be re-processed, "managed" and re-described in memory depending on already-held concepts and conceptual schema) as some sort of norm, in other words, the researcher adopts "pupils' own words" (pupils describe concepts by their own way/language, not repeat the contents from textbooks) as research data. Of course, sometimes a concept itself may already contain guiding factors within its verbal expression. For example, most students have already been "primed" with an idea of "shaking" and "something to do with the earth", from the mere reading of the word "earthquake". Nussbaum (1989) indicated that concepts themselves may frequently provide the organizing elements and guiding principles for most science lessons, as well as for scientific enquiry more generally and fieldwork.

Students may acquire concepts from sources including fiction rather than from textbooks. Through the interview questions, the researcher also hopes therefore to trace what are the major science resources for students, and to determine which of the science resources attract students' attention. Importantly too, the researcher hopes to gauge the quality of information obtained from such sources.

3.3.4 Interpreting students' ideas

It is obvious that students' ideas about earthquake/volcanic objects, events and related phenomena might be expected to reflect the background and understanding of their own former learning situations, as well as their own personal interests. As Claxton (1993) pointed out, however, "Being a subject in an experiment, however informal, is a novel social and cognitive experience that demands the selection or construction of knowledge and of knowledge-manipulation and expression procedures". From the reactions of interviewees and the data collected from the pilot study, it is apparent that what students manifest is not always the knowledge, quite simply, they have already, but that quite often they present to the researcher some sudden inspiration resulting possibly from the perceived requirements of the research context, or the stimulation of the question itself. As Claxton (1993) suggested, when students have this kind of "fresh" situation, most of them are ready and enthusiastic to co-operate with researchers with all types of responses, whether they really fully understand or not, and therefore the reliability of students' answers may well be jeopardized. Sometimes, it is the case that students try to "invent" a reaction in the heat of the moment. To avoid these distortions of the data, Von Glaserfeld (1989) and Johnson and Gott (1986) questioned the reliability and validity of evidence relating to students' concepts from another perspective. According to Johnson and Gott's (1986) theory, to discover how and what students think, one should rely on a more global interpretation of their answers, including body language. In fact, body language is an essential indicator in the study of student's concepts. (In cases in my research, if students tried to "produce" uncertain answers, they usually avoided eye contact with me.) However, body language is frequently disregarded. This became apparent quite often during the pilot study, while students were wondering if they should "produce" any answers to a question they were uncertain about. While the pilot studies were in process, some of the students seemed not sure how to respond to the interview questions. However, these students would not give up any chance of answering the questions, either by responding "I don't know", or "I have no ideas about this question"; rather, these students tended to choose to cast about longer and deeper in their mind. In these situations, unless I expressly told the students they were allowed to reply "I don't know", the students would generally maintain their "deep thinking".

It is clear from these and similar cases that, although most students' concepts are based on knowledge that they have already gained, sometimes students naturally try to "act" their role and to feel helpful. However, as Johnson and Gott (1986) indicated, most people most of the time shape their sense of the world according to what they have already known and build up on their own cognitive structure to react to stimulation (questions).

As mentioned earlier, throughout an interview, the researcher should employ "convergent questioning". In other words, when the researcher is not sure whether the student understands any particular question, or when the researcher focuses on one conceptual point, but enquires into it from a number of different angles, he or she probes the student's understanding of various aspects of the phenomena, in this way testing the reliability of the answers; Johnson and Gott (1986) spoke of what they called the "translation interface", in this context meaning that, during the interview procedure, it is necessary to pass over every question twice. This is suggested for the reason that, in the procedure of interview, what comes into play is not only the researcher's view and researcher's interpretation of the response, but significantly also the interviewee's (the pupil's), own interpretation of the question and own response (pupil's view). The double traverse here offers an opportunity to avoid the misinterpretation of questions and answers between interviewer and interviewee. Besides the "double traverse" and the underlying rationale behind it, Johnson and Gott (1986) concede the existence of "neutral ground", where the student understands what is the meaning of the question intended by the interviewer, and the interviewer understands the student's answer according to the student's intention too; for no one is about to build up another's meanings completely "from scratch", as it were.

3.3.5 Conducting interviews, recording responses and the principle of interview ethics

The interviews in this study were to be carried out individually in a classroom, one student at a time.

The major ethical discussion here includes the principle of applying interview permission, the principle of asking class teacher's assistance, the principle of one to one interview and the principle of maintaining good interaction with school.

The purpose for applying interview permission is because this is about lawful or legal procedure to carry out any activity in school. In other words, without interview permission, I was not allowed to do my research in school, neither to contact with any students.

Secondly, in applying for permission I can help the school authority to help me to complete my interview smoothly, unless the application is refused. Thirdly, the reason to ask the class teacher's help is because the class teacher should be the main manager in the classroom, the class teacher is also familiar with students' performance and able to help me to avoid most difficult situations. Fourthly, the reason that I adopt one to one interview is for carrying out the ideas of anonymous confidential, harmless result and voluntary effect, the main purpose is to make sure that students are able to express their original ideas without any misgiving.

To keep close interaction with school authority after interview is also necessary, as it provides a reciprocal benefit between school authority and the researcher. I have achieved my research purpose and had some convenience from school; therefore, it is a kind of duty, responsibility and morality to me to offer the general interview results to the school.

The detail interview procedures and application are presented below:

(1) Apply interview permission from School authority

In most cases, I delivered my interview application to head teacher's office; the application involved explaining the research purposes, the interview procedures, and interview questions. Sometimes, the head teacher or dean would ask me to have a private talk before they allowed me to carry out my research interview. When I delivered my application to junior high school, the chairman of commission on students' parents asked me to provide a detail explanation about my research interview in person, and after that I finally received the permission from school authority (signed by head teacher, dean and the chairman of commission on students' parents). It was a different situation when I applied the permission to senior high school, I was asked to introduce my interview procedure and detail to student association (apart from head teacher), and then they had a meeting with head teacher to discuss my application, in the end, I was allowed to use one of the science classroom as my interview room. My interview application to primary school did not need to go through students' union, but I had to explain my interview purpose to the head teacher and teachers' commission, and because of students' young age, therefore there was always a teacher to supervise the interview procedures.

(2) To ask assistance from the class teacher

The assistance from the class teacher was important; one of the main tasks was to divide the students into three groups according to their academic performance (upper, medium and lower levels). Class teachers had a better understanding of their students' academic performance than I did. To avoid embarrassing students and maintain students' self-respect, students were divided into three different colour groups, hence they would not know how they were divided, as soon as I called for next interviewee, all I needed to say was "next one, from orange/blue/green group please".

The class teacher also helped me to reduce misgivings from students, although at the beginning of interview, I explained the procedure of interview to each student and emphasized this interview was not a part of academic grading. However, I was a "stranger" to each student after all, therefore, class teachers endorsed my explanation again in person. I explained to the pupils that taking part in the interviews was voluntary. By following procedures (1) and (2) informed consent was obtained from participants.

(3) The procedures of interview

The students were interviewed one by one in a spare classroom using a tape recorder. I explained to the students that the interview would not affect their academic grades, as it was only for research purposes, and there was no need to record their name. My explanation and class teacher's endorsements were necessary, to put the students at their ease, and reassure them that they could answer the questions freely.

After the interview, I gave a small present (stationery: pencil, pen or rubber as they like) to each student as my appreciation.

(4) Feedbacks and Reciprocal beneficial interactions

As soon as I finished my interview in each school, I would summarize the general results and presented to school authorities as a feedback and reciprocal benefit. Usually the class teachers, head teachers, dean, parents' and students' representative would attend this short meeting, and quite often they were very interested in the general findings and asked me some relevant questions.

Each interview took about one hour, not including extra annotated drawings of the internal structure of the earth, volcanoes and crust movement. In Osborne and Freyberg's (1985) experience of interviewing students, especially young pupils, the interviewee can easily become obviously bored and start to respond with indifference if the interview process takes too long. This could have presented some difficulty for the study. Interview duration is another variable which affects the quality of the interview itself. For older students, this might not be a problem, but with younger students, it might become a major problem, with the difficulty in understanding students' ideas possibly taking longer than students' limited patience can easily tolerate. In this research, each student sat near the interviewer, who tried to put them at ease, and after that, to explain to the students what was about to take place. It was very important to make clear to the students that these interviews were for private study or interest, and that the results would not be published to anyone, including their parents, classmates or friends. During the process of interview, I had to keep reminding the students that it was better to answer "I don't know", "I have no idea" or "I am not sure" when the students really had no ideas about the questions, and that it was also important not to guess or to use the imagination in answering the questions.

Observations on verbal responses and body language were to be kept as written notes as a record, and audio-tapes used to record answers. All the details of the drawings, and additional written explanations are presented as appendices to this dissertation. Tape recordings were used as the results were to be collected as entirely and as unobtrusively as possible and as neutrally as possible. The use of a tape recorder suits some but not all circumstances; this depends largely on the individual reaction of each student, especially as when the audio-machine remains visible, it may cause students' performance to be inhibited. The tape recorder indeed has considerable benefits. No points are missed, the tape recorder decreases the chances of the researcher's prejudgment, and it also allows the interviewer to be attentive to the interviewee, without fear of missing information. However, it is unavoidable to make some mistranscriptions or misunderstandings, creating potential sources of error or prejudgment. As each interview proceeded, I had to pay attention to timing and interview pressure as well. It was absolutely crucial to pay attention to identifying the key points to the questions, all of which assisted in analyzing and illustrating the collected data. At the end of every interview, the students were asked to sum up their concepts and thoughts and also to refine anything that necessitated illustration. Socially appropriate shows of gratitude were extended for their attempts and for giving their time. 100 hours of verbal interactions were written down as formal reference.

3.4 General Aim of the Questions in the Interview

The questions in the first part (sections (I) and (II)) were intended to investigate broad concepts and enable easy comparisons and tracking of students' understandings at each age level. In this stage, the point was not to focus on right or wrong answers, but to see the type of response: (scientific answers, mythical answers, or the answer "don't know"). The existence and type of response was more important than its particular internal logic or "correctness".

The questions of the second part (section (III) and annotated drawings (IV)), explored the depth and broadness of knowledge that school students had already acquired regarding earthquakes and volcanoes. The results could also reflect the understanding and background students had about the local geological environment (Taiwan).

The value of giving students well-designed and thoughtful or fruitful questions has been recognized for some considerable time. Elstgeest (1985) believes that questions may be classified into several groupings - focusing, measuring and comparing questions. Both open and closed, and even person-centered questions have been used in science research (Harlen, 2000): open questions contain more possibilities for response than closed questions, which offer only a limited choice of answers. For drawing out students' ideas and concepts about earthquakes and volcanoes in this study, Vosniadou and Brewer's (1992) research ideas, on factual and generative questions, were relevant, because factual questions can offer firsthand data about students' thoughts on a theoretically principal point, but may do almost nothing to demonstrate their ability to apply these points from a generative point of view.

Some students, on being asked about the classification of earthquakes, for instance, may answer that there are detectable and undetectable earthquakes, having received this knowledge from television news or radio reports. Being asked what can you do during an earthquake or volcanic explosion, or what causes them, cannot easily be responded to properly with knowledge from public media alone. In accordance with Vosniadou and Brewer's (1992) suggestion, the students' responses to generative questions regarding objects, events and possible phenomena, in which the researcher is also interested, require the creation of a mental representation or model and the ability to use these mental representations themselves to provide answers.

This study has volcanic and earthquake events as the main selected topics. According to Symington et al (1981), such a consideration with dual focus usually strengthens the survey process, including descriptive capability and transfer of verbal descriptions to annotated drawings. In fact, the annotated drawings may play a role in defining, explaining, supporting and guiding the understanding of the internal structure of volcanoes and the Earth in this study, because drawing is likely to also reflect many other concepts, such as the shape, space, and even imaginary understanding, with the sequences of events and phenomena mapped onto a two-dimensional surface.

According to Lillo's (1994) research, over and above the obvious characteristics of drawing, a familiar exercise during general science lessons at primary level, it is an invaluable part of the teaching and learning process, as it can represent a student's understanding and gauge their understanding. Annotated drawings are extremely helpful in the process of understanding and explaining students' responses to particular questions (Symington et al, 1981). The great advantage of drawing is to support and clarify those ideas that cannot be expressed well verbally (Thamas, 1995). Having the students draw volcanic structure, the internal structure of the earth and volcanic explosions may reveal many details as interviews proceed. After this step, then I have to go further and ask the students to draw what caused the earthquakes, what causes a volcanic explosion and even what causes tsunami/seismic waves; these steps link to picture recognition, which will be used variously to present the theme. These included the shape, size and colour of volcanic and earthquake structures. In case there might be some mis-recognition or misunderstanding between students and myself, the simplest ploy is to ask students to mark and name any objects appearing on a drawing (annotation, Appendix 26,31,48,57,74 for examples). At any suitable opportunity during the research, the broad linking of questions and answers can be occasioned in something similar to "conceptual interviews" and "case and incident interviews". These two interview types have been reviewed by Osborne (1980), who believes that interviews about concepts and interviews about instances and events should occur naturally while the study is in progress.

3.5 The Pilot Study

3.5.1 Introduction

A Pilot study was carried out in order to test out the preliminary interview schedule and possible schemes of analysis. It was difficult logistically to carry out the pilot study in Taiwan. Pilot interviews were thus done in England. Although there are important cultural and geographical differences between the two countries in their belief systems and topography, it was considered that these would not invalidate a pilot study that was mostly aimed at exploring the face validity of the interview schedule.

The pilot study was divided into two parts. The first part focused on primary level students and the point was to find out whether the interview questions were fully understood by primary students. It was also to look for the possibility of question improvement, and finally, to try to analyze the pilot data.

Hence, the aims of the pilot study were:

1. To find any technical problems from the interview.
2. To test and verify that all the questions were suitable for use in the main research.

The pilot study was carried out at a Primary school, a secondary school and a college in southern England, with 5 students from year 3, 5 students from year 6, 5 students from year 9 and 5 students from year 12.. At the first day's interviews, the year 6 students had not fully understood the interview schedule used; therefore, I had to modify the interview schedule for the year 3 students. The second edition interview schedule was easier to understand than the first edition.

In the second edition, language modification was one of the key points. This was because, during the interviews, I found that, for primary level students, it was very difficult for them to understand formal sentences; in some cases, students misheard or even misunderstood the intended meaning of the formal sentence. This situation could have caused serious errors in the research results. On the second day of interviews, students seemed obviously to understand the meaning of the interview questions. The second interview schedule as used fully in the pilot is shown in section 3.5.2.

As described in section 3.5.5, ethical protocols were followed in order to gain pupils' informed consent. Pupils were told that their involvement was voluntary and that their responses would be related anonymously.

During the interview, I always had to deal with students' requests for feedback carefully. Students might ask the interviewer questions like "Am I right?", "Is this a correct answer?" or "So what do you think?", "What is the correct answer?" Of course, I could not answer these questions, because offering a professional answer to the interviewee might have affected their confidence in their own opinions. What I did was to give them a neutral response of various kinds, such as "It is hard to say" "It sounds interesting to me" or "It is too early to judge your answer". I had to avoid getting involved in any conceptual interaction or asking leading questions. The school authorities usually wanted to know the general outcome with the interview results, so I would report to the headteacher or class teacher about daily results when I finished my work every afternoon.

3.5.2 Findings from the Pilot Study

From the students' feedback, I found that some responses suggested the need for modifications to the interview questions for the main study. Generally speaking, these responses were from the following aspects:

(a) The use of language

Students might not be familiar with the terminology of Earth science; therefore, I tried to use common language to replace the terminology as much as I could. Because the point of the interviews was to establish the students' overall ideas about earthquakes and volcanic events, the first priority was to have the students understand the meaning of the questions before examining their understanding of Geological terminology.

Because the students were from primary level and senior level, even using common language, I had to keep it as simple as possible, so that everyone could understand the first time, to avoid students' wasteful repetition.

(b) The order of questions

The order of questions can help to determine the students' conceptual structures and their possible developmental history. This means setting a suitable question order to prevent students from obtaining answers based on other questions. If the question order is set from easy to difficult as a test level, then students' understanding can be relatively easily determined. More importantly, this can help the interviewer to arrange and analyse the data conveniently later on.

The following shows the original interview schedule as applied in the pilot study. The final interview schedule is shown in section 3.8.

Pilot Interview Schedule

Students' ideas on volcanic and earthquake events

School:
Year Group:
Name:
Age:
Gender:
Date:
Have you heard about earthquakes?
Have you heard about volcanoes?
Where did you learned about them?
As Prompts: (yes/no) TV/Film/Video, In Book/Comic/Newspaper/Magazine, On Computer, On Holiday, In Play, School, Other (Specify)

(I) Earthquake Events:
1. What is an earthquake?
2. What happens when an earthquake occurs?
3. What does an earthquake look like?
4. How does an earthquake happen?
5. Where do earthquakes happen?
6. When does an earthquake happen?
7. How often do earthquakes happen?

8. How long does it take each time an earthquake happens?

9. What should we/you do before, during and also after the earthquake?

10. Have you ever experienced an earthquake in any other country/place? If so, talk about it.

11. Are you afraid of earthquakes? Why?

(II) Volcanic Events:

1. What is a volcano? (or have you heard about volcanoes?)

2. What does a volcano look like?

3. How does a volcano erupt?

4. When does a volcanic explosion occur?

5. Where do volcanic eruptions occur (in addition to the one you have already mentioned?)

6. How often do eruptions occur?

7. How long does each volcanic eruption go on?

8. What should we do during/ after an eruption?

9. Have you ever experienced a volcanic eruption? If so, would you please talk about it?

10. Are you afraid of volcanic events? Could you please tell me the reason(s)?

(III) Further Interview Questions

1. Is there any link between volcanic events and earthquake events? And could you tell me the reason(s)?

2. How do you regard volcano/volcanic activities in the U.K? (for example: is it a kind of natural resource, a kind of energy or it is just an unavoidable hazard? Could you explain why you think so?

3. How do you regard earthquakes in the U.K? (For example: Is this a natural hazard or a necessary energy release?)

4. How do you think of the current status of volcanoes in the U.K?

5. How do you think of the status of earthquakes in the U.K and around the world?

(The wording of the last two questions was slightly modified for the main study, which was conducted in Taiwanese language, which translated better as "what is your understanding of the current status of volcanoes/earthquakes in Taiwan and around the world", wording which also relates better to research question 1.)

3.5.3 Results of the Pilot Study

With the results, I began typifying students' responses in four categories:

1. Those that demonstrate understanding of scientific (rather than "alternative" or "mythic" etc) conceptions, and that are scientifically correct;
2. Those that are incorrect factually, but which display scientific conceptualization nevertheless;
3. Those that are non-scientific; and
4. No knowledge.

In their answers, it was apparent, predictably, that older students, who had had more exposure to formal education, also had a "more scientific" understanding than younger children. Exposure to media coverage, too, seems to have informed some of their responses to the final questions in the second part of the interview ("What would you do before/during/after an earthquake?" etc), as well as their responses to "What happens in an earthquake/volcanic eruption?" in the first part.

I tabulated the responses, dividing them into the four types mentioned. From such a small sampling in the pilot study, it is difficult to draw much in the way of conclusions from the data, but it provided a useful exercise preparatory to the main study.
Some concerns arising from the pilot study were how to arrange the interview schedule, the "influences of students' attitudes" and the adoption of a "yes-no" question style at the beginning of the interview. "Yes-no" questions could identify whether or not a student has heard about volcanic and earthquake events. This can also help the researcher to decide which interview questions deserve more time and which need less. In other words, "yes-no" questions can detect what kind of question is of value to ask (for example: when a student answers "yes, I have ever heard about this", this can save a lot of time subsequently and ensure a more effective interview, making the interview data more systematic).

After several "yes-no" questions, the second part of the interview schedule consisted of a number of open questions. Here most students had good reactions, which meant most students could understand each question well and each question seemed to provide enough space for discussion. However, in response to open questions, students still resorted to guesswork frequently. With questions such as "Are earthquakes predictable/can scientists predict earthquakes?" most students were not sure at the beginning, but if they had some time to consider it, eventually their own ideas came out. Of course, some students already knew that earthquakes can only be predicted at short notice, but quite a lot of students had no idea when they were asked this question the first time. It was interesting to learn whether they thought earthquakes were predictable or not, as students always had some reasoning behind their answers, and therefore, I believe this style of questioning can avoid leading questions successfully.

The third part of the schedule involved annotated drawings. This part offered more open space for students; students could present any ideas from their imagination by drawing pictures of earthquakes and volcanic eruption.

A number of problems become evident in the first part of the pilot:

1. Students might find out some information from other questions, and use this information to answer other questions.

2. The questions were not complete enough. There were some concepts that could not be elicited, whereas some questions seemed to be used to discover the same concepts.

3. Some students could not understand the meaning of the questions.

3-1 Students could not understand the meaning of some of the sentences. This was due partly to general language difficulties.

3-2 Students could not understand the terminology of the questions. This was due more specifically to limited exposure to scientific forms of discourse and limited comprehension of the terminology of Earth Science.

4. Students frequently countered interview questions with questions of their own and/or sought confirmation from me, the interviewer, over the 'correctness' of their responses.

A number of practical measures suggested themselves from a consideration of the above sorts of problems encountered in the pilot study: firstly, of course, to give further thought to the arrangement and order of the questions. This might involve increasing the number of questions, as well as reformulating many. I soon realized that particular attention needed to be given to language use for it to be comprehensible or at least fairly familiar to the students at whatever level and age I was researching. My own response too to students' responses needed to be monitored and possibly modified, especially in offering responses that were at the same time 'neutral' and encouraging. The results of all this reconsideration were (a) a modified questionnaire, and (b) a somewhat modified approach to my own role and interview style.

3.6 Sampling for the Main Study

In the sampling, I tried to focus on the points of objectivity, accuracy and representativeness. Therefore, the students were selected from different academic levels, different study grades and different family backgrounds. Difference in gender could be ignored, as it is not the focus of this research.

I asked the class teachers to do the sampling for me, because I believed that each class teacher had an understanding and record of their students in general. It was hoped that this would help me to have a more objective, accurate and representative sample, and also save time for the whole interview procedure.

Sections 3.2 and 3.3 presented the criteria used in the sample selection, and explained location and who were involved. Thus, I had prepared for research questions 1, 2 and 3. The reason for selecting students of different academic ability and study grade was to maintain the objectivity of the interview results, a matter of concern regarding the accuracy of research questions 2 and 3.

3.7 The Interview Schedule

After a re-consideration of the interview procedure of the pilot study and the literature, the interview schedule I arrived at was the following (The first section asking about general background and sources of knowledge of earthquakes/volcanoes remained the same as in the pilot study.):

3.7.1 Earthquake Events

0. Do you think earthquakes are predictable?
This question is the first question about earthquake events, so I intended only to elicit a very basic idea and first reaction from the students.

1. What is an earthquake?
As another preliminary question, this could provide a rough indication of students' understanding of earthquakes.

2. What happens during an earthquake?
This question allowed the researcher to first detect whether or not students had ever experienced an earthquake, and secondly, to probe their understanding of earthquake phenomena a little further.

3. How long does an earthquake last?
Following on from the idea of question No.2, the intention here was to test the concept of duration. The result could be extended to compare whether duration was relevant to students' sense of intensity or even fear.

4. What is it like before/during/after an earthquake?

The answer to these questions could be a verbal answer (status description) or students could be asked to draw what an earthquake looks like; this helped the researcher to understand representations of the real image that students had of earthquakes.

5. What causes an earthquake to happen?

The purpose of this question was to probe the students' understanding of cause(s). As with the question above, the researcher could also ask students to do an annotated drawing. The drawing typically should show some detail of the Earth's structure.

6. How often do earthquakes happen?

The understanding of frequency is essential, because it relates to location and causes; the combination of answers may show the students' thinking.

7. Where do earthquakes happen?

The aim of this question was firstly to test the geographical knowledge of countries besides Taiwan, where earthquakes might be expected to occur, and secondly, to discover if the students had ever experienced an earthquake in a different place. Finally it tested whether the students could indicate the correct location of any country/area where they believed earthquakes occurred.

8. Have you ever experienced an earthquake in any other country/place? If so, talk about it.

This question forms a link with others, whereby the researcher can examine the students' sense as to whether there may be any different causes of earthquake occurring in different places.

9. Are you afraid of earthquakes?

This question was mainly to detect any link between emotional reaction and logical thinking about earthquake events.

10. What should we/you do before, during and also after the earthquake?

In fact, this is a single question, asking students how they might face the earthquake in time sequence. It is also concerned with students' preparation for dealing with the event of an earthquake.

3.7.2 Volcanoes and Volcanic Events

This part of the questioning was basically in the same style as the questions of the last part, but the questions concerned volcanoes and volcanic activity, mostly eruption.

0. Do you think volcanic eruptions are predictable?

The same as the first question in earthquake events and for the same purpose.

1. What is a volcano?

Again, as a preliminary question concerning volcanic concepts, the first question was intended as a "foundation" question, to lead students to the larger questions of volcanic events as a whole.

2. What happens during a volcanic eruption?

This question allowed the researcher to first detect whether or not students had any ideas about volcanic eruption, and secondly to probe their understanding of volcanic phenomena.

3. How long do volcanic eruptions last?

In Taiwan, students have had no first hand experience to draw on, so it was a tough question for students, but they could still answer this question through common sense, scientific film, text books or real experience abroad. Hence, the sources of the answers were key points to be noted as well.

4. What does it look like before/during/after a volcanic eruption?

This question allowed students to do some annotated drawings, with the aim of learning whether students could point out external differences/similarities between a normal mountain and a volcano.

5. What causes a volcano to erupt?

The answering of this question also allowed students to do annotated drawings. But the key difference between this question and the previous one was that it sought students' ideas regarding the internal structure of volcanoes. The answer might involve further the internal structure of the Earth.

6. How often do volcanic eruptions happen?

This was to check on knowledge about active volcanoes, dormant volcanoes and extinct (dead) volcanoes through the question of frequency of eruption around the world.

7. Where do volcanic eruptions occur?

This is a question about geography and location again. I asked students to point out where volcanic eruptions occurred all over the world. When possible, the researcher could ask students to point out any volcanic zone they knew, for example, the Circum-Pacific Basin.

8. Have you ever experienced a volcanic eruption?

Here, the main aim was simply to investigate how many students had experience of real volcanic eruptions. If students answered "Yes", then they were asked to indicate the location, and also to describe the occasion. If the answer was "No", that was an understandable and reasonable result. But whatever the answer, it was of value for comparing with results from other questions, and in this comparison, I could determine whether students with actual experience of a volcanic explosion had better ideas about coping with volcanic hazard than those who had no such experience.

9. Are you afraid of volcanic eruptions?

This was to find out what students think of volcanoes/volcanic events. Although responses may be more emotional than based on real knowledge, the researcher could still make speculation and some associations from among the responses.

10. What should we/you do before/during/after a volcanic eruption?

This is not within the background of most Taiwanese students; nevertheless, this question can determine how students might deal with such a frightening natural hazard. Students' reactions could be separated into two different types, according to whether they used their imagination, or where they followed input information from television programmes, magazines, encyclopaedias or other sources.

3.7.3 Further/Combined Interview Questions

These further interview questions were prepared in order to investigate more advanced, more organized, deeper or even more systematic thinking.

1. Are earthquakes and volcanoes linked in any way? And could you tell me the reason(s)?

This question was intended to encourage students to integrate two individual concepts that might be seen as separate events. This question should not suggest or lead students to believe one way or another. The researcher was able to see whether the students knew of any link between the two systems. This was the strongest test of their knowledge.

2. How do you regard volcanic activity in Taiwan? (For example: is it a kind of natural resource, a kind of energy or it is just an unavoidable hazard? Could you explain why you think so?

This question was meant to elicit different views and opinions from students. In some way, volcanic activities and earthquakes are both particular forms of energy release. However, at the moment, there is no way we can harness them advantageously. Here, the research point was to discover the students' notions regarding natural resources and hazards.

3. How do you regard earthquakes in Taiwan? (For example: Is this a natural hazard or a necessary energy release?)

This question is a little different from the last one. The difference is that an earthquake might be more readily regarded as a natural hazard; for Taiwanese people it is difficult to see it as a natural resource. On the other hand, earthquakes are necessary releases of energy, and their failure to occur regularly would build up even greater catastrophic pressure. The main point was to see whether or not students had any ability to identify the similarity and differences between earthquakes and volcanoes.

4. How do you think of the current status of volcanoes in Taiwan?
Through this question, the researcher was able to probe students' views about the status of volcanoes in Taiwan. The answer might be that the country has active, dormant or dead volcanoes. The researcher could also ask students how they can differentiate between them, and then evaluate the criteria through which students assemble their system of classification and also their understanding of volcanic structure.

5. How do you think of the status of earthquakes in Taiwan and around the world?
This is a wide ranging question, because an earthquake's effects, especially a middle or powerful earthquake, can spread hundreds of miles. This question was not only to measure the understanding of earthquake zones from students, but also concerned the scale and severity of earthquakes.

3.8 Chapter Summary

In this chapter I have attempted to outline how I conducted my research and to relate it to the findings and concerns of previous research in similar fields.

Starting out with a consideration of sampling and the question of representativeness in a cross-age study, I outlined the ways I could best get a representative group of informants, choosing a sample of students of top, middle and lower academic level from public (i.e. state) schools rather than from the higher achieving and more "selective" private schools of Taiwan.

I then looked at what seemed to be the benefits of conducting face-to-face interviews as a method of collecting the sort of data I was after, in the relatively in-depth and focused research I hoped to conduct, and with the relatively small sample size I envisaged. It seemed the preferable method, allowing for greater flexibility and for the employment of a number of means of eliciting responses, giving sufficient time for each interviewee to be asked follow-up questions, so that thinking processes and conceptual structures behind responses could be studied. I have noted in passing the unavoidably social nature of the interaction, the view of the interview as a "conversation" within a larger context of social discourse (though retaining relevance to the topic).

In sketching out the rationale behind my choice of questions for the interview schedule, I looked at the choice of "open" and "closed" questions, deciding upon a structure beginning with a small number of closed questions (such as "Have you ever experienced/heard about earthquakes?") leading on to more open questions, designed to reveal the interviewees' understanding in greater depth. I outlined my proposed interview schedule, in which factual questions (e.g. "What is an earthquake?", "What does a volcano look like?"), aiming to elicit declarative or simple descriptive responses, lead on to "generative" questions, where it is "construct validity" rather than "factual validity" that is sought, in order to trace the conceptual structures that provide the "theoretical" framework to students' understanding (or misunderstandings). These questions typically required causal explanations and/or reference to underlying causes from which to draw inferences, as well as reflections upon the students' own experiences and knowledge. It is here, predictably, that issues of "cognitive conflict" and the constructivist aspects of learning were likely to be raised. In this way I hoped to achieve the stated objectives of the research, namely to uncover the development of genuinely scientific concepts in children as they mature in their understanding through the process of science education.
I also mention the general purpose of using annotated drawings as an assistant method to collect data in this chapter. By observing pupils' individual drawings, I can find out whether or not their two drawings show any connection, or any further relevant concepts which didn't appear in the interview results, and more importantly, I am able to compare the similarity and difference from pupils' drawings and their interview results. Further analysis of drawings are introduced in the following chapter, some of the analysis are intergraded displayed together with interview results.

This chapter has outlined my research schedule, first the pilot study in the U.K, and then the main study in Taiwan, described in the next chapter (focusing on data analysis and findings).

Chapter 4 Data Analysis and Findings

4.1 Introduction

The data analysis was conducted in two stages. In stage 1, all the data were closely examined (students' feedback). In this stage, the analysis focuses on the microcosmic range, which included personal reactions, individual concepts, and the effect of understanding. This was all about detailed information collection and closely focused detailed observations. After the detailed analysis, stage 2 collated similarities and differences from the data and then revealed general tendencies in the macro-cosmic range. This contained potential blind spots for particular study level students, and also contained the analysis of internal and external knowledge affecting students' concepts. Then, I classified these students' responses into the following 4 types, as stated earlier:

(T1) Understanding scientific concepts and with correct interpretation.
(T2) Having some scientific concepts but with incorrect interpretation.
(T3) Lacking scientific concepts or with misconceptions (which might include old sayings, guessing and mythology).
(T4) No knowledge.

The main reason why I classified pupils' responses into above 4 types was because I tried to avoid falling into dichotomy, such as "with or without certain concept", "yes or no", or "do or do not understand", because from many studies: Driver et al (1985), Dove (1998) and Ross et al (1993) for examples, the results showed that pupils' understandings might adjoin different types of idea; hence, the above 4 types which I re-organized might provide a gradual classification, it sorts out the different level of understanding but also retains the coherence between each type.

All the analysis is based on three main analytical procedures, which are

1. Synthesis
2. Arrangement and classification

and

3. Induction and explanation

Several main points arise in this chapter regarding analysis of the research data in terms of procedures, including Synthesis & Arrangement, Re-Arrangement & Classification and Induction & Explanation. The above 3 procedures are determined by consulting other relevant researches: Bezzi (1989), Schoon (1989), Tuckman (1999), Good (1963), Dove (1997) and expert's publication (Rothery, 2000). From the way of data management in these researches/publications, I found the above 3 producers were effective, systematic and convenient to deal with huge data, which collected by interview or questionnaire in particular. There were 100 pupils interviewed in my study, therefore I consulted these resembling researches and re-designed these similar procedures to analyze my data. These procedures are clarified as follows:

1. Synthesis & Arrangement

From each study grade, for each question or for similar questions, there is usually a considerable amount of raw data to be examined. I gathered all the data together, and classified it according to its characteristics (Examples of raw data are shown in appendices 1-12).

1-1. Geological/Science concept analysis

This is to check whether or not students' answers contain scientific concept(s), and secondly, geological ones. Students may express non-scientific notions. The scientific ones (geological and non-geological) may be of different types. The categories of responses are as follows:

(a) Understanding scientific concepts and with correct interpretation.

Students are able to answer the question using correct concepts. For example, to the question "What causes a volcanic eruption?" students might answer: "The Earth accumulates enough energy, and this energy raises lava temperature and increases the pressure; finally, it erupts from the weakest part of the crust." In this case, students understand the scientific concept of volcanic eruption and are able to apply the scientific concepts correctly.

(b) Having some scientific concepts but with incorrect interpretation.

To continue the above example, to the same question, another student's answer might be: "In some places, where it is too hot, the hot weather heats the lava and increases the pressure; finally it erupts from the weakest part of the crust."
In this case, the student demonstrates an understanding of several scientific concepts, such as the fact that hot weather could heat up things and that volcanic eruptions are caused by strong pressure. However, students are not able to apply these scientific concepts correctly, making the mistake that hot weather can raise lava temperature.

(c) Lacking scientific concepts or with misconceptions (which might include old sayings, guessing and mythology).

Students may use some kinds of myth to explain geological phenomenon. For example, some students might believe that earthquakes occur because God is angry with human beings, and creates earthquakes to punish people.

(d) No knowledge

This group of students has no relevant ideas at all regarding the questions, giving responses such as "I don't know", "I have no idea" or "I am not sure".

Here, scientific conception means: (1) of, used in or involved in science, (2) using methods based on those of science, (3) having, using or needing skill or expert knowledge. Wrong conception means: (1) not true or incorrect, (2) not suitable or not the most desirable regardless of whether the concept is scientific or not.

In addition to the above four categories, the term "scientific" is further divided into geological and non-geological concepts, geological meaning: of or relating to the interaction or knowledge of the lithosphere. This analysis could bring out new findings from the data, because there are further possible categories:

(e) With geological concepts.

Students' concepts relate to geology directly, such as plate tectonics, body waves, seismic waves and seismic zones. These are directly geological concepts.

(f) With non-geological concepts.

Students' concepts relate to geology indirectly or only as general science concepts, such as ground water acidity, solution, temperature, pressure, thermonuclear reaction and pressure gradient force.

For precise results, it will be useful to fine-tune the analysis so that scientific understanding or misinterpretation are classified according to geological and non-geological concepts, giving the possibilities of **(a) + (e), (a) + (f), (b) + (e)** and **(b) + (f).**

To continue the previous example, when students answer the question "What causes a volcanic eruption?" the answer from the students could be that the Earth accumulates enough energy and this energy raises lava temperature and therefore increases the pressure; finally, it erupts from the weakest part of the crust. The above answer is (a) + (e), because there are geological concepts and they are scientifically correct. However, students also talk about pressure and temperature increase. Although these are also correct, they are not geological concepts specifically, but more like general science concepts. Hence, this part of the answer is (a)+(f), which means that the student was able to answer this question with both geological and non-geological concepts.

(b)+ (e)

This means that students use a scientific and also a geological concept, but are scientifically not correct in responding to the question. For example: a student might believe that regional metamorphism causes earthquakes to occur. In this case, regional metamorphism is a geological and also a scientific concept, but it has nothing to do with earthquakes.

(b)+ (f)

This means that students use a scientific and also a non-geological concept, but that their answer to the question is not scientifically correct. For example: a student may indicate that the greenhouse effect causes volcanic eruptions; in this case, the greenhouse effect is not a geological concept but it is a scientific concept. However, the greenhouse effect has nothing to do with volcanic eruptions.

The benefit of introducing geological and non-geological concepts to the data analysis is to discover more information from students' feedback, such as when or where do they start to hold geological concepts for explaining particular events or what kind of knowledge do they use in explaining geological events, and does it belong to general science or Earth science?

1-2. Classifying similar descriptions

Students may have similar ideas for each question; these ideas might come from the same underlying concepts, for example: solidity (volcanic bomb, rocks, house falling), liquidity (lava flow, mud flow) or gaseous concepts (steam, smoke). This kind of classification can be a great help in identifying how students think about geological events (which is what this research is about) and how their understanding develops.

1-3. Other aspects

Students may or may not be afraid of earthquakes and volcanic events, and, in some cases, students might be afraid of only one of the above events. What I am looking for from their attitudes and answers is to find out why they are/are not afraid of these events. There must be a reason for it, and, by comparing the same student's response to other relevant questions, it might be possible to find out what is the reason, logical or otherwise, in the student's mind.

Students' fear of nature's power could reflect their existing understanding of geological phenomena and allow us to observe how they deal with geological hazards, because, in the process of dealing with hazards, students could show further correct or incorrect knowledge of the topic, whether coming from public media or elsewhere.

2. Re-Arrangement & Classification

Data re-arrangement & classification are used in order to arrange similarities and differences in the data, and to suggest changes in the order of the data, as different data constitution could offer very important information. The way of doing this sort of analysis includes the following.

2-1. For each question, comparison of the differences and similarities at each study grade

Students may have a variety of ideas for each question. From comparing each study grade, I can determine changes and development in any relevant concept. This comparison can be a means to assess the coherence of students' thoughts, or it may help to track the development of students' concepts between Year 3 primary level and Year 3 senior level, for example.

The main value of this comparison is that it helps us to see the developmental gaps and consider possible causes for these gaps.

2-2. At each study grade, comparison of the differences and similarities in each response.

Even at the same study level, students may still have very different answers for each question. For example, Primary Year 6 students might have very different ideas about how long an earthquake lasts, but more in common in their answers as to how often earthquakes occur. However, Senior high school Year 3 students might have more in common in both of the above two questions. The difference between these two study grades can be used to compare the understanding and misunderstandings in students' ideas overall. In this part of the analysis, the focus is not on comparing the differences in each individual student (although this is admittedly a necessary part of the process of measuring the understanding range at each study level). The main point at this stage is rather to compare the understanding range. Moreover, in noting what kind of understanding/misunderstanding is at the overlap between each study level and what is the new understanding/misunderstanding at each study level, through such comparisons it should also be possible to discover if students' understanding increases steadily, and cumulatively or in leaps and geometrical progressions. In either case, it would be interesting to find out the reasons.

3. Induction & Explanation

This is to find out the general trend for each study level and also across every similar notion. Basically, each study level could have a different response trend to each similar notion, or students might have quite closely converging points of view. In either case, by reviewing the trends, we may find some clues as to how students construct their understanding.

The task is mainly to compare the average response at each study level with the average response of students overall. This can help contrast the accuracy and the conceptual development at each study level, or it might be used to find out reaction intensity to each concept and each level as well.

Although the research data comparisons are mainly between students, the data is also examined to see how scientifically and geologically correct the responses are. To undertake this level of comparative analysis, responses are compared with accepted understanding of volcanoes and earthquakes.

4.2 The Analysis of Students' Drawings

4.2.1 The principle of analyzing students' drawings

The main function of pupils' drawings in this study is to be a supplementary comparative material with interview data. There are total 200 pupils' drawings collected from interview, and there are five steps to analysis students' drawings;

1. Synthesis and arrangement
2. General and detail classification
3. Comparison of the difference and similarity
4. Matching up the annotation
5. Induction and explanation/ interpretation

Basically, the above 5 procedures are determined by adopting the same concepts and similar categories as in interview data, as well as consulting some other relevant studies: Chula (1998), Lillo (1994), Symington et al (1981), Thamas (1995), Van Sommers (1984), Wiegand (1991), Weigand (1995) and Wiegand (1998). From the way of interpreting drawings in these researches, the above 5 procedures were systematic for analyzing annotated drawings. These procedures are clarified as follows:

First of all, I arrange all the drawings according to different school grading (study level) in order, and then I divide all of them into 3 sorts, which are volcanoes, earthquake events and combined phenomena (volcanoes and earthquake events), secondly, I pick up some obvious characteristics from these drawings, for example: volcanic status, earthquake status, people's reaction, damage, and casualty. These two classifications aim to select different view of drawings from students, and then I am able to compare the similarity and the difference from these classifications (step 3), and in step 4, I try to match up students' annotation and their drawings; step 3 and 4 are related and almost carried out at the same time, step 5 is to find out the general trend for each study level and also across every similar notion. The task is mainly to compare the average response at each study level with the average response of students' overall. In this final step, I put my focus on the frequency counts of characteristics and patterns which are revealed in the drawings.
According to Chula (1998, p22) frequency counts are helpful to identify patterns in the drawings. While students may not consider themselves to be artistically inclined, it is revealed that they have access to and draw upon a wealth of visual symbolism (Chula, 1998. p.23), derived from many possible sources, such as cartoon drawings (ibid, p.25). O' Shea (1999, p.4) in his study of Singaporean 14-year olds also refers to the approximation of nature using a cartoon drawing style to rapidly communicate meaning.

O' Shea (1999, p.6) indicates that children's drawings may be affected by the perspective they already have of the world. Thus, the volcano is always given a landscape setting, whereas the earthquake may have an internal setting (inside a building), an external (in the street) or a symbolic representation only (for example the simple line drawing of tectonic plates in Appendix 66). This is clear from the number of stick figure drawings in the Taiwanese sample and, for example, the symbolization of "shaking" objects or buildings, indicated by short lines (<<   >>) surrounding the objects.

4.2.2 Approach to analysing the drawings

The analysis of drawings gives good insights into how young students perceive catastrophic events (Lillo, 1994), such as earthquakes and volcanoes. At the same time, and for a very good reason, the drawings are a very easy tool to work with. Lillo cited that often they represent one simple idea; sometimes they incorporate two or three ideas, but rarely would four or more ideas be included in a drawing. (Examples are given below.)

Such representations of ideas are described as the "characteristics" of the drawings, and as they frequently recur as themes, they are quite easy to categorise.

Differences were found between volcano and earthquake drawings. There is a clear reason for this. The physical product of a volcano is visible (even if only in pictures or on film). It is possible to see smoke, lava and rocks in movement, ash, gas, a mushroom cloud, and so on. These are all mentioned in the interviews (Table 4.6), and appear (as examples) in the drawings in Appendices 26, 79, 59, 22, 77 and 39, respectively. It would be more unusual to see stick figure drawings or illustrations of the Earth's internal structure in drawings of volcanoes.

With earthquakes, on the other hand, it is harder to see what physically happened, other than in terms of the effects of damage to buildings and "shaking". A number of categories emerge from this (examples given below): the first is a simple graphic of a seismic event; drawings can be classified further according to whether the setting is inside or outside a building, according to whether stick figures are included or not, and according to whether damage is slight or serious.

The simplest graphic representation is in Appendix 66, which uses just three lines to represent tectonic plates moving in opposite directions (indicated by arrows). A similar drawing is made in Appendix 45, with 5 lines and one arrow, Appendix 46 (lines for plates with arrows) and Appendix 49 (lined plates and the written word "fault"). Appendix 35 is an imaginative drawing of a global fault system. Appendix 72 is a symbolic representation of an epicentre surrounded by three concentric rings.
Examples of slight effects of earthquakes are in Appendices 13, 21 and 71, which respectively show a vase "jumping" on a cupboard top, a small vase falling and a man sleeping in bed while the room and the light shake. Serious damage to buildings (breaking and falling) is shown in Appendices 14, 16, 19 and 69. Appendix 53 is an example showing more than one "characteristic", namely shifting earth and a tall building toppling onto another one.

Another theme of earthquakes picked up in the analysis is that of "unpredictability". This is perfectly represented in Appendix 17 by two separate stick figures, which are almost identical, except that the second one is shaking (surrounded by short lines representing movement, as in cartoon drawings) and the first is not. Above the latter is written (in Taiwanese characters) "It hasn't happened yet" and above the other "It is happening".

Another theme is shelter. For example, Appendix 51 shows a man crouching under a table with hands covering head for protection. Other drawings show figures moving away calmly in the street, some running, and some occasionally looking panicked.
The above examples show the broad categories found as the analysis proceeded. These findings could then be used to compare with the interview data.

Schematic Diagram of Data Analysis and Findings

The procedures of data analysis:

1. **Synthesis & Arrangement**
2. **Re-Arrangement & Classification**
3. **Induction & Explanation.**

Categories of data analysis:

1. **Microscopic level**
2. **Macroscopic level**
3. **Annotated drawings**

Students' possible concepts:

(a) Understanding scientific concepts and with correct interpretation.

(b) Having some scientific concepts but with incorrect interpretation.

(c) Lacking scientific concepts or with misconceptions (which might include old sayings, guessing and mythology).

(d) No knowledge

(e) plus geological concepts.

(f) plus non-geological concepts.

(a)+(e) Understanding scientific concepts and with correct interpretation plus geological concepts.

(b)+(e) Having some scientific concepts but with incorrect interpretation plus geological concepts.

(a)+(f) Understanding scientific concepts and with correct interpretation plus non-geological concepts.

(b)+(f) Having some scientific concepts but with incorrect interpretation plus non-geological concepts.

Findings

The data in the tables below are presented in order (senior group first). The next sections describe the results obtained for each interview question across age levels, starting with results for the questions on volcanoes.

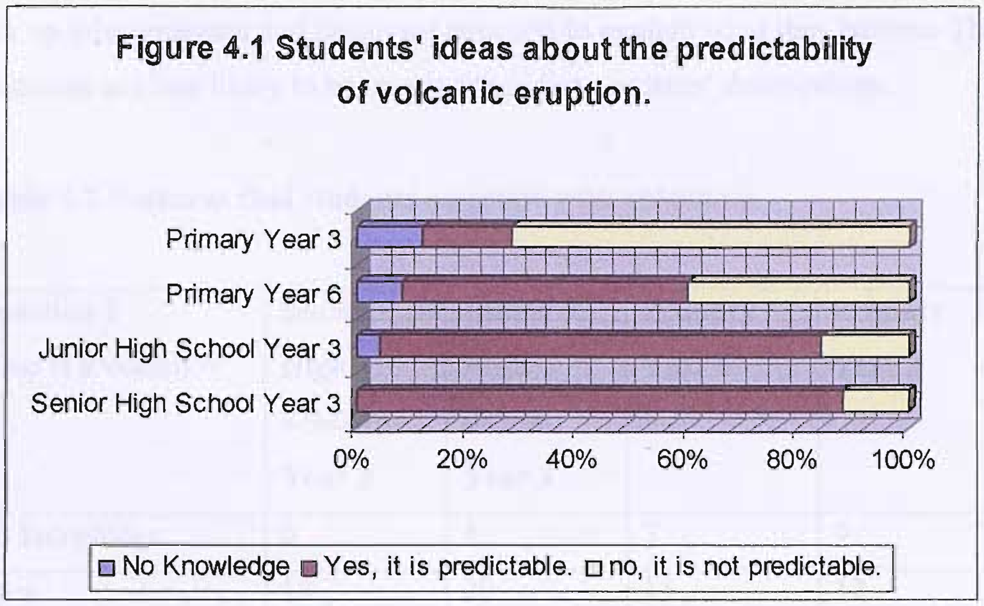
4.2.3 Data Analysis (Volcanic Events)

To see the interview transcript and nature of the data about Volcanic Events, please refer to appendices 1-4.

Table 4.1 Students' ideas about the predictability of volcanic eruptions

Question 0 Are volcanic eruptions predictable?	**Senior High School Year 3**	**Junior High School Year 3**	**Primary Year 6**	**Primary Year 3**	**Total**
No knowledge	0	1	2	3	6
Yes	22	20	13	4	59
No	3	4	10	18	35
Total number of responses	25	25	25	25	100

(If every child gave a single response, there would be 25 for each school year column total.)



Only 6 students did not know whether volcanic eruptions are predictable, 5 of whom were from primary school. More than 50% of students believed that scientists can predict volcanic eruptions, and more than half of this 50% students were from secondary school. Students in secondary school have already had formal Earth Science education, which might increase their understanding of volcanic eruptions.

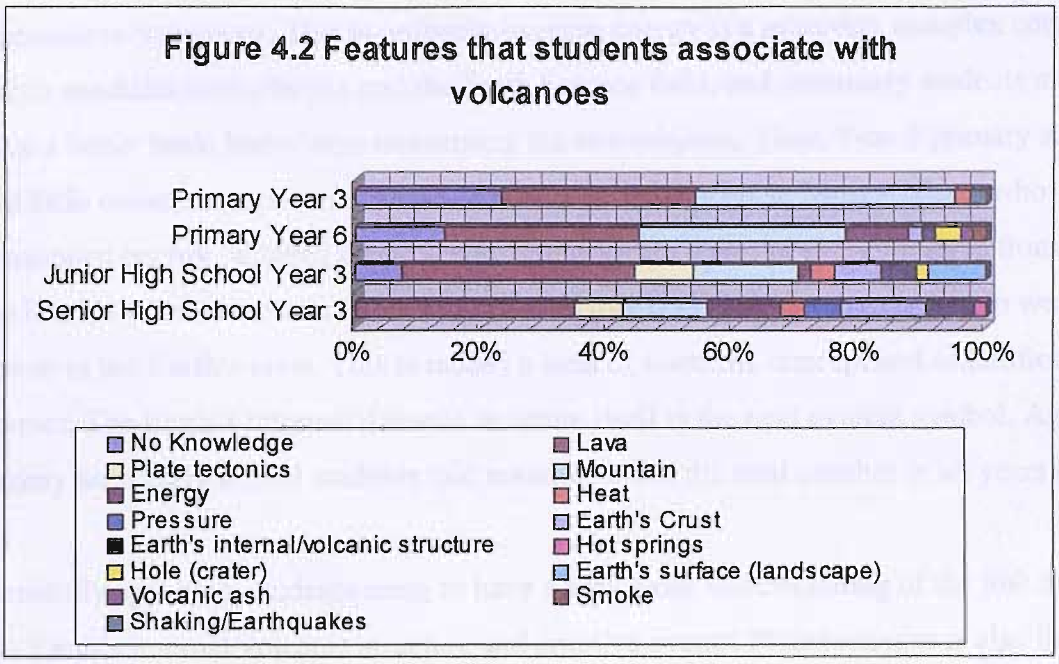
Students who are from higher grades are more inclined to believe that volcanic eruptions are predictable. A number of students indicate that when volcanic eruptions are about to occur, there is smoking and shaking, terrestrial heat goes up and atmospheric composition may show a high content of sulphur. Such answers normally show understanding of scientific concepts and correct interpretation. Although some of those who believe that volcanic eruptions are predictable, especially primary students, they partially understand a scientific concept but make an incorrect interpretation, for example: "Yes, when lava position goes up, it might erupt." or "Yes, when lava flows much more quickly than usual, it might erupt." Some other young students' answers are unscientific, wrong or incomplete, such as "Yes, but I don't know how to predict it."

From the above examples, we can suggest that primary students, though they may possess the correct knowledge, for example, that volcanic eruptions are predictable, may not actually hold any theoretical concepts; they might just hear the positive answers from others or just repeat the information they have read. Primary students, moreover, easily mix up other relevant and irrelevant concepts to explain what they believe. These kinds of situations are less likely to happen in secondary students' descriptions.

Table 4.2 Features that students associate with volcanoes

Question 1 What is a volcano?	**Senior High School Year 3**	**Junior High School Year 3**	**Primary Year 6**	**Primary Year 3**	**Total**
No knowledge	0	4	7	9	20
Lava	18	20	15	12	65
Plate tectonics	4	5	0	0	9
Mountain	7	9	16	16	48
Energy	6	1	5	0	12
Heat	2	2	0	1	5
Pressure	3	0	0	0	3
Earth's crust	7	4	1	0	12
Earth's internal/volcanic structure	4	3	1	0	8
Hot springs	1	0	0	0	1
Hole (crater)	0	1	2	0	3
Earth's surface (landscape)	0	5	0	0	5
Volcanic ash	0	0	1	0	1
Smoke	0	0	1	0	1
Shaking/Earthquakes	0	0	0	1	1
Total number of responses	52	54	49	39	194

(If every child gave a single response, there would be 25 for each school year column total.)



One-fifth of students had no idea about what a volcano is, more than 80% students of those being primary students.

Lava seems to be the most commonly cited feature of volcanoes at all study levels. 12 students mentioned it at primary Year 3 level, and 20 at Junior high school Year 3. The second most common representation is that of a mountain. In fact, about half of the students indicated it. At primary level, in both Year 6 and Year 3, 16 students believed that all volcanoes are a kind of special mountain with lava. The number holding this idea was double that among secondary students. There might be two possible reasons. Firstly, when secondary students describe volcanoes as mountains, they visualize only continental or island ones, and not underwater ones. Secondly, in the language textbook for primary Year 3 level, one of the texts indicates that Mt. Fuji is a volcano; a number of primary students only relate to it, as the only volcano they know in the world. Mt. Fuji, in fact, has not erupted for a few hundred years, and nowadays it is famous mainly for its shape, as a popular skiing area and for its high quality water used in the production of whisky. This leads to a misunderstanding of what a volcano really is.

The third important feature related to volcanoes is energy under the Earth's crust. These two aspects are much discussed at secondary level, especially by senior high school students. None of the Year 3 primary students mentioned energy or Earth's crust with reference to volcanoes. This is probably because energy is a relatively complex concept, which straddles both Physics and the Earth Science field, and secondary students might have a better basic knowledge concerning the two subjects. Thus, Year 3 primary students had little coherent response in terms of energy or Earth's crust. Most students who mentioned energy believed that volcanic eruptions are a sort of energy release from within the Earth's internal structure and also believed that lava always comes out from weak points in the Earth's crust. This is indeed a kind of scientific concept and scientifically correct. The Earth's internal/volcanic structure itself is the next evident symbol. Again, it is mainly secondary school students that mention it, but the total number in all years is only 8.

Generally speaking, students seem to have a very weak understanding of the link between the Earth's internal/volcanic structure and eruptive events. Plate tectonics is also listed (as the fourth key symbol for students). It seems that only secondary school students have any idea about it, yet they cannot clearly describe how plate movements affect volcanoes.

Only a minority of senior level students suppose that pressure could be one of the factors in volcanic activity, and they believe that pressure affects the inside of the volcano just as the pressure acts inside a boiler. This thought could be regarded as a scientifically correct concept. Only one student (from senior high school) believed that hot springs could be another volcanic indicator, and, interestingly, there is no information or acknowledgement of the link between volcanoes and hot springs in the Earth Science textbooks. The reason why this student feels that there should be some kind of link between them is because of his personal interest and curiosity regarding hot springs. This curiosity and interest pushed him to study the matter and to make a close observation of hot springs. After close observation and self-research, he felt fairly sure that hot springs are one of the key indicators of volcanoes. From this student's case, it appears that students' understanding might be sparked off effectively by self-motivation and interest.

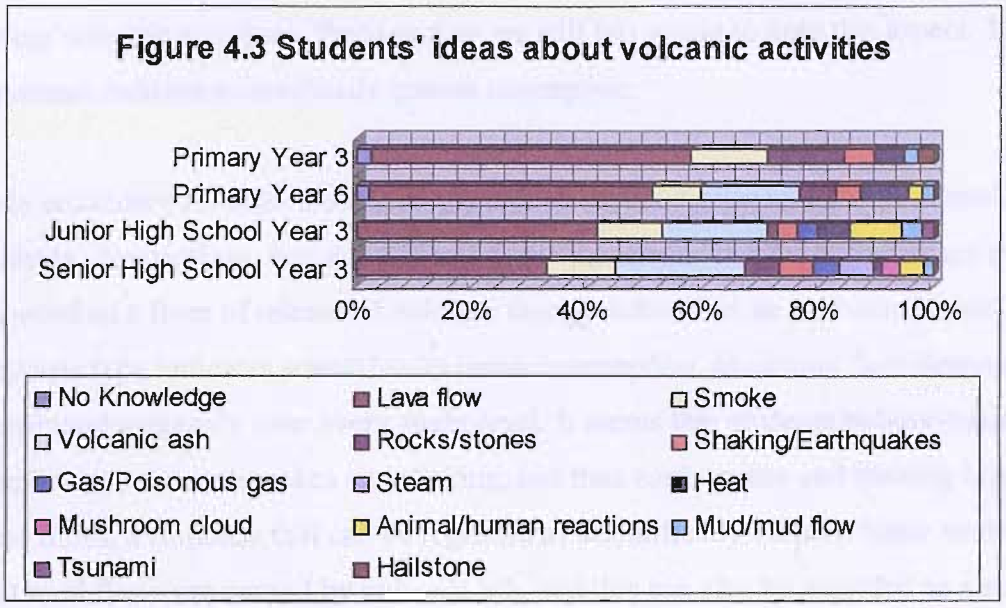
Volcanic ash, smoke and shaking/earthquakes are hardly ever mentioned as an indicator of volcanoes, and students who talk about them are all from primary level. This suggests that primary students may hear these terms, but they do not fully grasp their significance. Quite often, these students think that if even just one of the above factors occurs, it could be regarded as volcanic activity. This kind of reaction indicates scientific conception but incorrectness.

Every single student at secondary and upper primary levels (Year 6) had around 2 responses or ideas concerning this question, but Year 3 primary students gave only 1.56 responses on average to this question, lower than the overall average of 1.94, for this question. This shows that students understanding of what a volcano is increases significantly after Year 6 in primary school.

Table 4.3 Students' ideas about volcanic activities

Question 2 What happens during a volcanic eruption?	**Senior High School Year 3**	**Junior High School Year 3**	**Primary Year6**	**Primary Year3**	**Total**
No knowledge	0	0	1	1	2
Lava flow	22	23	23	21	89
Smoke	8	6	4	5	23
Volcanic ash	15	10	8	0	33
Rocks/stones	4	1	3	5	13
Shaking/Earthquakes	4	2	2	2	10
Gas/ Poisonous gas	3	2	0	0	5
Steam	4	0	0	0	4
Heat	1	3	4	2	10
Mushroom cloud	2	0	0	0	2
Animal/human reactions	3	5	1	0	9
Mud/mud flow	1	2	1	1	5
Tsunami	0	1	0	0	1
Hailstone	0	0	0	1	1
Total number of response	67	55	47	38	207

(If every child gave a single response, there would be 25 for each school year column total.)



Most students stated that lava flow is the most common phenomenon during a volcanic eruption, and this popular notion is distributed averagely over each study level, although some students think that lava just stores up too much energy inside the volcano and flows little by little rather than flowing away like a river, a point of view that seems to be using scientific concepts, but it is not scientifically correct. Almost 90% of students mentioned lava, in different ways. The second highest common phenomenon stated was volcanic ash, though only about one-third of students mentioned it, and three-quarters of those were at secondary school, which might indicate that volcanic ash is not common knowledge in primary school; at least, none of the Year 3 primary students understood it, and only 8 Year 6 primary students talked about it at all. The third common phenomenon to the students is smoke. Once again, there are more secondary students that mention it than primary students, and, in some cases, students only observe that smoke can cause air pollution, dark skies and dark clouds, but they never talk about how the smoke arises, which might indicate that primary students are interested in the results more than the causes.

Rocks, shaking, heat and animal/human reactions are less commonly cited phenomena. Of the students who indicate that stones or rocks "fly" out of the crater and that ground shaking is heavy, it seems that senior high school students have more concern about shaking /earthquakes than other study levels. In fact, for heat, rocks and animal/human reaction matters, there is always a particular age category of students interested in it, but out of Year 3 primary students, nobody was able to talk about animal/human reactions during volcanic eruptions. Perhaps they are still too young to note this aspect. These responses indicate scientifically correct conception.

Only secondary students remark on gas and steam activities (senior high school). From students' descriptions, it is not difficult to see that steam and gas activities are normally regarded as a form of release of volcanic energy rather than an individual event. This response type indicates scientifically correct conception. Mud/mud flow description is distributed averagely over every study level. It seems that students believe volcanic eruptions cause earthquakes and shaking, and then earthquakes and shaking bring about mud flows, a response that can be regarded as scientifically correct. Some students think that mud flows are caused by volcanic ash, and this can also be regarded as a scientifically correct conception. These ideas are more common at secondary level.

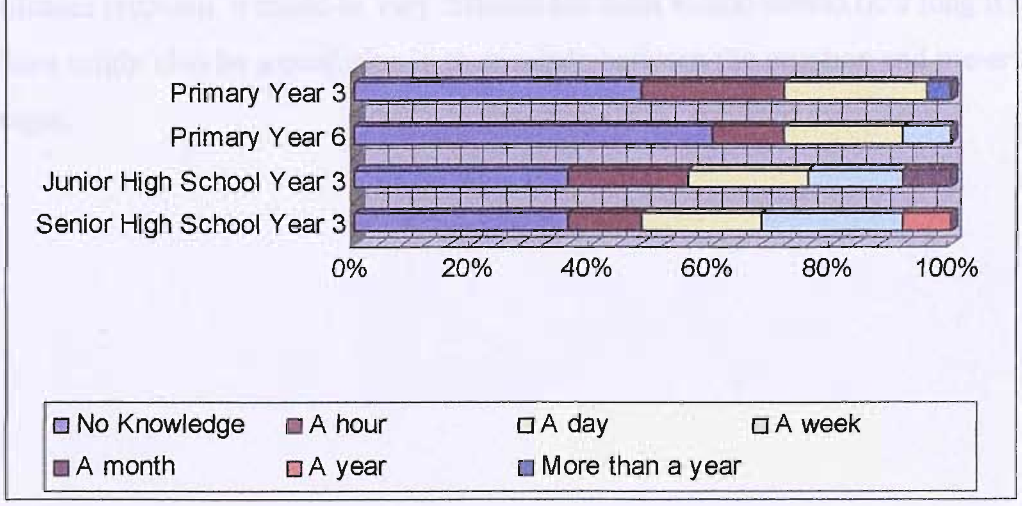
Tsunami and hailstones are very special cases amongst students. One junior high school student talked about tsunami. His idea originated from a film, but what he suggested is scientifically correct. Another Year 3 primary student mentioned hailstones just because she believed that volcanic ash might cause unusual atmospheric activity. This is a typical case of having scientific concepts but incorrect interpretation. There were two primary students who had no knowledge at all about the phenomena related to volcanic activity. The average response rate for senior high school students was 2.68, 2.20 for junior high school students, 1.88 response for Year 6 primary students and 1.52 for Year 3 primary students. The overall average was 2.07 responses. From the above data, it can be seen that students have more ideas about "what happens during volcanic eruptions" at junior high school level.

Table 4.4 Students' ideas about the duration of volcanic eruptions

Question 3 How long do volcanic eruptions last?	Senior High School Year 3	Junior High School Year 3	Primary Year 6	Primary Year 3	Total
No knowledge	9	9	15	12	45
A hour	3	5	3	6	17
A day	5	5	5	6	21
A week	6	4	2	0	12
A month	0	2	0	0	2
A year	2	0	0	0	2
More than a year	0	0	0	1	1
Total number of responses	25	25	25	25	100

(If every child gave a single response, there would be 25 for each school year column total.)

Figure 4.4 Students' ideas about the duration of volcanic eruptions



Almost half the students had no knowledge as to how long volcanic eruptions last. The lack of knowledge was more common at primary level, with 50% more responses than secondary students (27:18). Most students believe that the whole process of a volcanic eruption should be complete in a day. About one-fifth of all students have this idea almost equally distributed across each grade. These students understand the scientific concepts and their answers are scientifically possible, although volcanic eruptions can last for longer.

One-sixth of students expect volcanic eruptions to last only one hour, with again even distribution between secondary and primary level. This group lacks or has a wrong scientific conception (perhaps just guessing). Only about one-eighth of the students had a relatively reasonable concept of the duration of an eruption lasting about one week. Most of those were from secondary level, with slightly more from senior high school. No one responded “a week” at Year 3 primary level. Two junior high school students believed that the duration of an eruption should be about 1 month. This duration is still in a reasonable range, but they could not offer any explanations for their idea, which may indicate guesswork rather than knowledge.

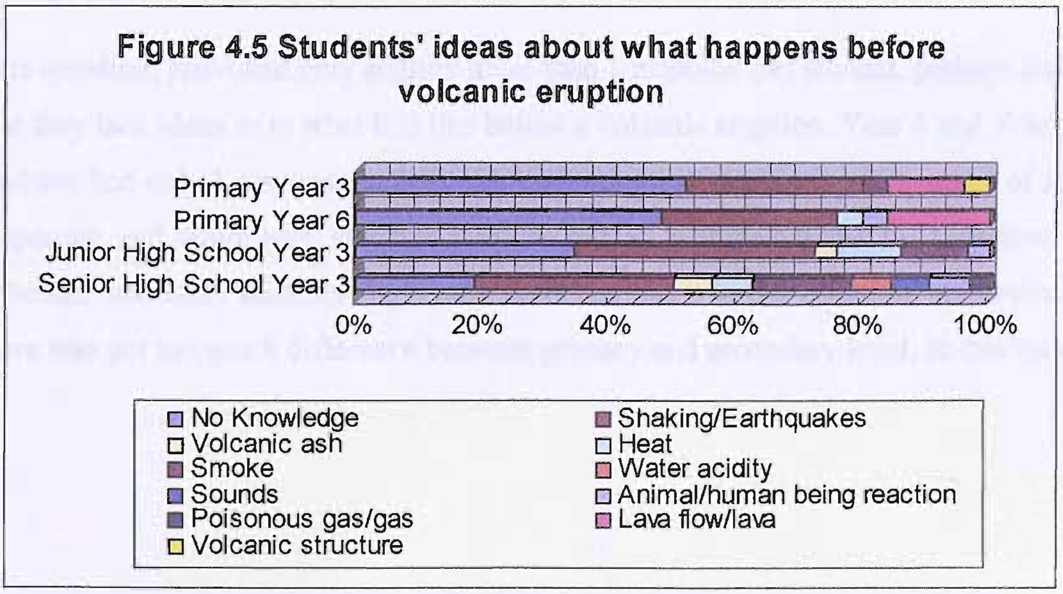
The rest of the students’ responses may also be classified as guesses, as they could not explain their idea or use logic. Two senior level students believed that eruptions could last up to a year, and 1 primary student insisted on more than one year.

In this question, each student had only one possible response, and only one third of students had a reasonable one. This suggests that, if students have never experienced a real volcanic eruption, it could be very difficult for them to understand how long it might last. There might also be a confusion in their minds between the eruption and pre-eruption stages.

Table 4.5 Students' ideas about what happens before volcanic eruption

Question 4-1 What does it look like *before* a volcanic eruption?	Senior High School Year 3	Junior High School Year 3	Primary Year 6	Primary Year 3	Total
No knowledge	6	10	12	13	41
Shaking/Earthquakes	10	11	7	7	35
Volcanic ash	2	1	0	0	3
Heat	2	3	1	0	6
Smoke	5	3	0	1	9
Water acidity	2	0	0	0	2
Sounds	2	0	0	0	2
Animal/human being reaction	2	1	1	0	4
Poisonous gas/gas	1	0	0	0	1
Lava flow/lava	0	0	4	3	7
Volcanic structure	0	0	0	1	1
Total number of responses	32	29	25	25	111

(If every child gave a single response, there would be 25 for each school year column total.)



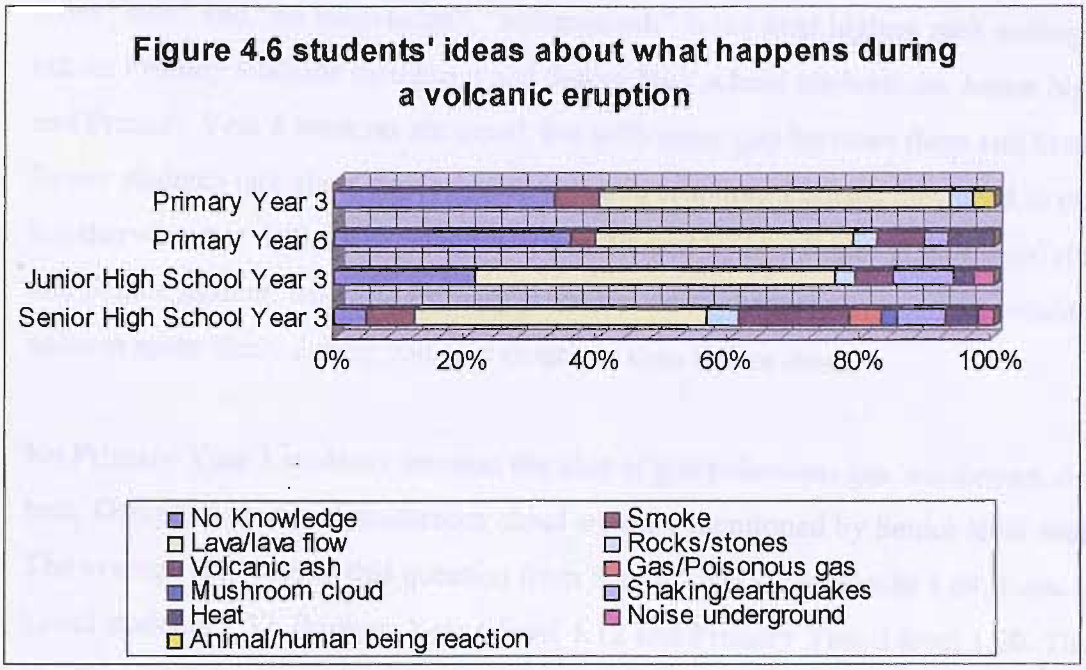
It seems, in summary, that there are more primary students than secondary students who have no knowledge of what it is like before a volcanic eruption, and about one third of students indicate either shaking or earthquakes as one of the main phenomena. In fact, secondary students seem to have more grounding than primary students in this area. Their idea is based on a scientifically correct concept. Other secondary students mentioned volcanic ash, heat and animal/human reaction; at primary level, no-one mentioned volcanic ash, but a Year 6 primary school student mentioned heat and human reaction. Students usually emphasize the way animals/humans react to unusual phenomena. For example, people feel heat (senior high school student), people can hear the noise underground (senior high school student). Primary students may not have the ability to explain properly, but simply describe, for example, animals with extraordinary reactions. Whatever the description, the difference is that Year 6 students can only talk about the general situation; for example, they know the animals have different behaviour, but they cannot give details, while secondary students have more concrete events to describe, such as people feeling the heat, or the temperature rising. Senior high school students seem to have more understanding of animal/human reactions before a volcanic eruption, and their idea contains a scientific concept which is correct. One Year 3 primary student stated that the volcanic crater could split open before eruption. This is the only description involving volcanic structure, and that from primary level. He obtained the information from the "Newton" magazine. This might suggest that science magazines could attract young students' attention and help them gain better scientific knowledge. Here, the student's response contained a concept that was scientifically correct.

This question, provoked only slightly more than 1 response per student, perhaps indicating that they lack ideas as to what it is like before a volcanic eruption. Year 6 and Year 3 students had only 1 response each, junior high school students gave an average of 1.16 responses, and senior level students 1.28, the overall average being 1.11. Therefore, although secondary students might have more responses to this question, academically, there was not too much difference between primary and secondary level, in this instance.

Table 4.6 Students' ideas about what happens during a volcanic eruption

Question 4-2 What does it look like ***during*** a volcanic eruption?	**Senior High School Year 3**	**Junior High School Year 3**	**Primary Year 6**	**Primary Year 3**	**Total**
No knowledge	2	7	10	10	29
Smoke	3	0	1	2	6
Lava/lava flow	18	18	11	16	63
Rocks/stones	2	1	1	1	5
Volcanic ash	7	2	2	0	11
Gas/ Poisonous gas	2	0	0	0	2
Mushroom cloud	1	0	0	0	1
Shaking/earthquakes	3	3	1	0	7
Heat	2	1	2	0	5
Noise underground	1	1	0	0	2
Animal/human being reaction	0	0	0	1	1
Total number of responses	41	33	28	30	132

(If every child gave a single response, there would be 25 for each school year column total.)



Compared with Question 4-1, fewer students had no knowledge regarding what it is like during a volcanic eruption. It seems that at both primary and secondary levels, the number of students with no knowledge had clearly reduced, and indeed at each study grade, not dissimilarly. Most students had a wrong idea about ground shaking and earthquakes mainly occurring before eruptions rather than during eruptions, but older students had more correct interpretations younger students, such as that ground shaking and earthquakes may still happen even during volcanic eruptions. Unfortunately, this kind of correct concept is not widespread among all levels of students.

Up to 63% of students indicated lava/lava flow as the most common phenomenon. 72% of Junior and Senior students held this idea and 44% and 64% in Years 6 and 3, respectively. The percentages were less in the Primary Year 3, mainly because of the higher number with 'no knowledge.' These students not yet had any formal Earth science lessons, but Year 6 students have a broader knowledge to enable them to provide a wider range of answers. Primary Year 3 students, because of limited background knowledge, mostly go for lava/lava flows, which is the most commonly held view. After students have had formal Earth Science lessons at secondary level, they realize that lava/lava flows should be the commonest phenomenon during volcanic events, but are ready to recognize other phenomena.

After “lava” and “no knowledge”, “volcanic ash” is the next highest rank amongst students, but no Primary students mention it and Senior high school students do. Junior high school and Primary Year 6 students are equal, but with some gap between them and Senior level. Fewer students talk about noise during volcanic eruption. Perhaps they need to experience it, otherwise it is difficult to imagine. It is indicated by one Junior High school student and one Senior student, while no Primary school students discuss it; in younger students’ minds noise is more likely during volcanic eruptions than before them.

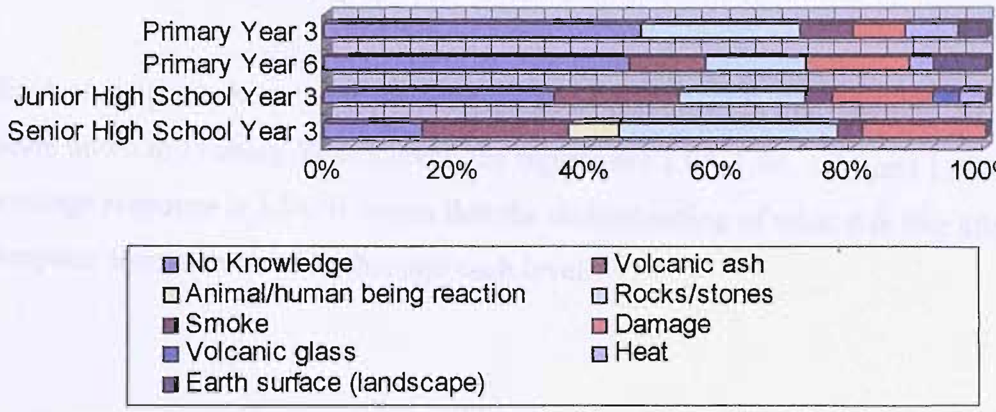
No Primary Year 3 students mention the idea of gas/poisonous gas, mushroom cloud and heat. Gas/poisonous and mushroom cloud are only mentioned by Senior level students. The average response to this question from Senior level students was 1.64, from Junior Level students 1.32, Primary Year 6 level 1.12 and Primary Year 3 level 1.20. The overall average response from all students was 1.32. It seems that students had gained more knowledge from Junior high school level upwards.

Table 4.7 Students’ ideas about what happens after a volcanic eruption

Question 4-3 What does it look like ***after*** a volcanic eruption?	**Senior High School Year 3**	**Junior High School Year 3**	**Primary Year 6**	**Primary Year 3**	**Total**
No knowledge	4	9	12	12	37
Volcanic ash	6	5	3	0	14
Animal/human being reaction	2	0	0	0	2
Rocks/stones	9	5	4	6	24
Smoke	1	1	0	2	4
Damage	5	4	4	2	15
Volcanic glass	0	1	0	0	1
Heat	0	1	1	2	4
Earth surface (landscape)	0	0	2	1	3
Total number of responses	27	26	26	25	104

(If every child gave a single response, there would be 25 for each school year column total.)

Figure 4.7 Students' ideas about what happens after a volcanic eruption



Just over one third of students (37%) had no ideas about what it is like after a volcanic eruption. This figure is higher than for responses to what it is like during volcanic eruptions (29%), but less than what it is like before volcanic eruptions (41%). Students who seem to know nothing about what happens after volcanic eruptions, are mostly at Primary level. Only 16% of Senior level students and 36% of Junior level students expressed no knowledge, but at Primary Year 6 and Year 3, 48% of students had completely no idea in response to this question. It seems that higher grade students had more ability or confidence to deal with the question.

Primary Year 3 students were blank concerning volcanic ash, animal/human being reaction and volcanic glass. Apart from the notion of volcanic ash, the other notions only had responses from two Senior high school students and one Junior high school student; so probably at each study level, students lack ideas concerning what it is like after a volcanic eruption. Yet, a number of students are aware of the relationship between volcanic ash and volcanic eruption, and Senior students seem to have more notions than Junior and upper Primary students. The first and second well-known concepts are rocks/stones and damage. The common notion of damage is distributed over all study grades, averagely, though of course there are some differences. As regards the idea of rocks/stones, Senior level students had more positive responses than any other grades.

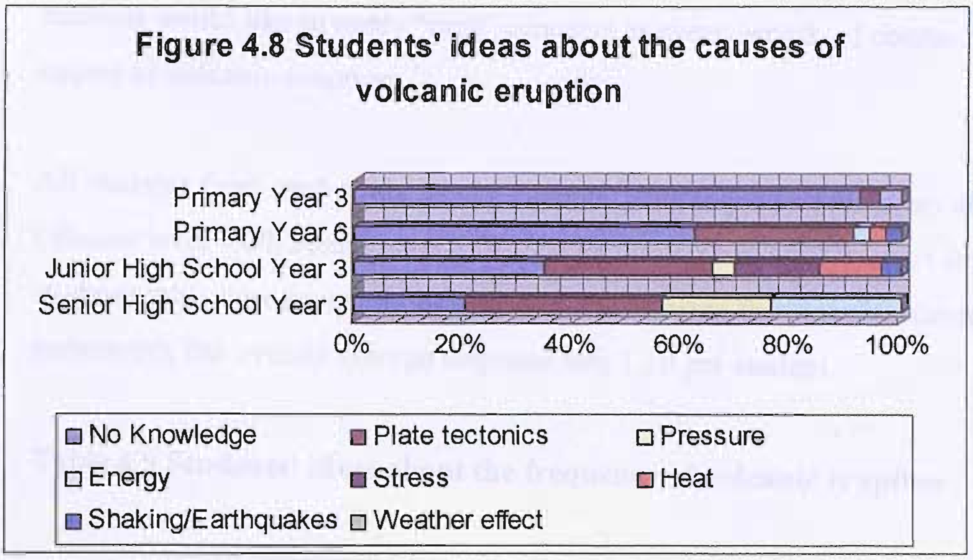
Interestingly, the notion of Earth surface formation (landscape) is only indicated by Primary students. This might be caused by differences by which Primary students seem to regard volcanic power as a main element in landscape formation, whereas Secondary students do not seem to, having broader knowledge of other elements of landscape formation.

Each study grade has a very similar number of responses to this question. From Senior level down to Primary Year 3 level, the figures are 1.08, 1.04, 1.04 and 1.00. The overall average response is 1.04. It seems that the understanding of what it is like after a volcanic eruption increases steadily through each level.

Table 4.8 Students' ideas about the causes of volcanic eruption

Question 5 What causes a volcano to erupt?	**Senior High School Year 3**	**Junior High School Year 3**	**Primary Year 6**	**Primary Year 3**	**Total**
No knowledge	5	9	21	23	58
Plate tectonics	9	8	10	0	27
Pressure	5	1	0	0	6
Energy	6	0	1	0	7
Stress	0	4	0	1	5
Heat	0	3	1	0	4
Shaking/Earthquakes	0	1	1	0	2
Weather effect	0	0	0	1	1
Total number of responses	25	26	34	25	110

(If every child gave a single response, there would be 25 for each school year column total.)



58% of students had no idea about what causes a volcano to erupt, but more than two thirds of those students were from Primary level. 88% of Primary students could not respond to the question, compared to 28% of High school students. It seems that to give an answer as to what is the cause of an eruptional event needs more complex understanding and comprehensive background knowledge.

For Primary Year 3 students, Plate tectonics, Pressure, Energy, Heat, and Shaking/Earthquakes could not be linked to the main causes of volcanic eruption. Primary Year 3 had the only student to believe that weather could be the cause of volcanic eruption. This indicates that younger students might think that temperature rising could affect volcanic eruption.

Senior level student responses focused on Plate tectonics, Pressure and Energy. These three matters are highly connected in some cases. This suggests that Earth Science teaching might have impacted on Senior level students.

Other than for Primary Year 3 students, Plate tectonics is a common cause of eruption for most students, at each study level. It is discussed often and it seems that students are able to accept the idea to clarify how volcanic eruptions occur. The concept of Pressure is only mentioned at Secondary level. This might indicate that Physics concepts are also involved; the students who indicated a lot of ideas about Stress, Heat and Shaking/Earthquakes were Junior students, whereas no Senior students talked about these factors. In the Junior High school curriculum, Stress, Heat and Shaking are first introduced here. Presumably Junior students would like to apply "new" concepts to every aspect, of course including the causes of volcanic eruption.

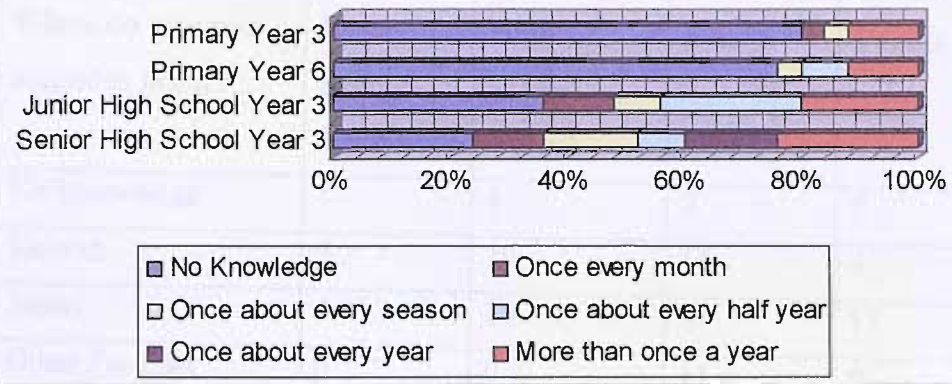
All students from each study level gave approximately equal numbers of responses (Senior level 1.00, Junior level 1.04, and Primary Year 3 1.00), apart from Primary Year 6 students who were more enthusiastic about answering this question (average 1.36 responses); the overall average response was 1.10 per student.

Table 4.9 Students' ideas about the frequency of volcanic eruption

Question 6 How often do volcanic eruptions happen?	**Senior High School Year 3**	**Junior High School Year 3**	**Primary Year 6**	**Primary Year 3**	**Total**
No knowledge	6	9	19	20	54
Once every mouth	3	3	0	1	7
Once about every season	4	2	1	1	8
Once about every half year	2	6	2	0	10
Once about every year	4	0	0	0	4
More than once a year	6	5	3	3	17
Total number of responses	25	25	25	25	100

(If every child gave a single response, there would be 25 for each school year column total.)

Figure 4.9 Students' ideas about the frequency of volcanic eruption



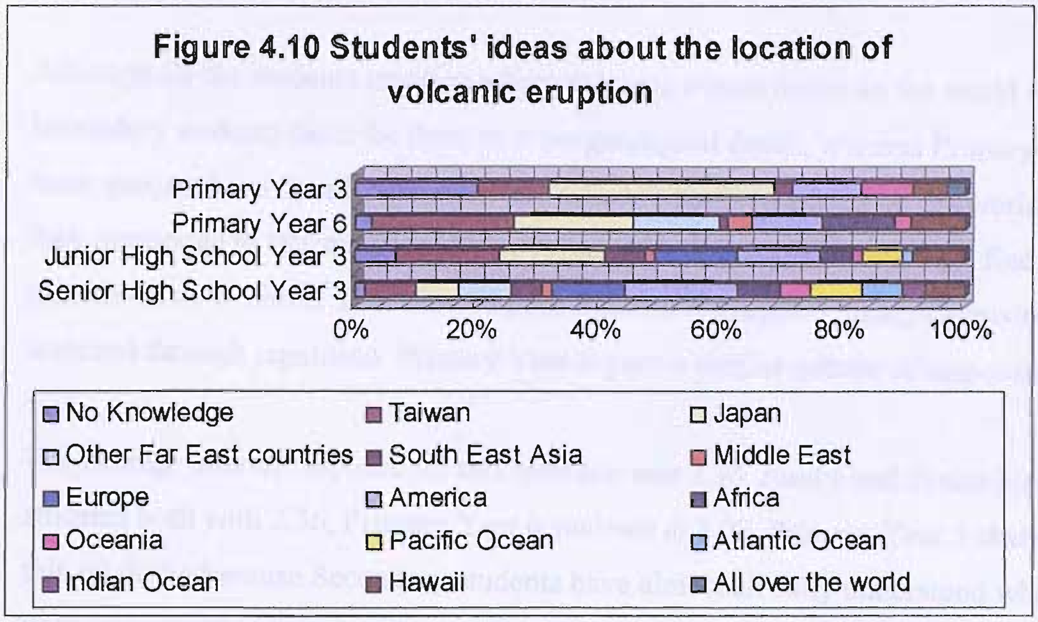
More than half the students could not answer about the frequency of volcanic eruptions, but 72% of these were from Primary level. Junior and Senior students had more ideas about how often volcanic eruptions happen.

Interestingly, most students believe that volcanic eruptions happen usually less than once a year, which means that most students who were able to respond did so correctly, the majority of those being Secondary students. Occasionally, in some places, volcanic eruptions happen more often, maybe once a year; students who know this are at Senior high school level only. The rest of the students think that they happen about every half year, every season or even every month. Primary students, however, seem to lack all idea about the question. Overall, each student had only one response to this question, and Senior high school students had the best correct knowledge, closely followed by Junior and upper Primary students, but with Primary Year 3 students far behind the average level.

Table 4.10 Students' ideas about the location of volcanic eruption

Question 7 Where do volcanic eruptions occur?	**Senior High School Year 3**	**Junior High School Year 3**	**Primary Year 6**	**Primary Year 3**	**Total**
No knowledge	1	4	2	7	14
Taiwan	5	10	18	4	37
Japan	4	10	15	13	42
Other Far East countries	5	0	11	0	16
South East Asia	3	4	1	1	9
Middle East	1	1	3	0	5
Europe	7	8	0	0	15
America	11	8	9	4	32
Africa	4	3	9	0	16
Oceania	3	1	2	3	9
Pacific Ocean	5	4	0	0	9
Atlantic Ocean	4	1	0	0	5
Indian Ocean	2	0	0	0	2
Hawaii	4	5	7	2	18
All over the world	0	0	0	1	1
Total number of responses	59	59	77	35	230

(If every child gave a single response, there would be 25 for each school year column total.)



Students with no idea about where volcanic eruptions occur numbered 7 or less at each study level. Most students realize that Taiwan, Japan and America have volcanoes, but it seems that there are a number of students who do not grasp the idea that the existence of volcanoes does not necessarily mean volcanic eruptions. While Senior and Junior students can understand this, Primary students do not. An obvious example is that of Primary students who do not realize Taiwan is a volcanic island, and do not indicate that volcanic eruptions (used to) happen in Taiwan. However, when they realize that Taiwan is a volcanic island, they normally say that eruptions occur in Taiwan, despite the fact that its volcanoes are actually dormant. The same situation happens when they talk about volcanic eruptions in Japan. Quite a lot of Primary students talk about volcanic events in Japan rather than in Taiwan, and the main reason for this is that Mt. Fuji is cited as a Japanese volcano in Primary Year 3 language textbooks.

Secondary students recognize that the existence of volcanoes does not necessarily mean volcanic eruption, and many Junior high school students even emphasize "Volcanic eruptions used to occur in Taiwan".

Only Secondary students indicate that volcanic eruptions can happen in the ocean, especially the Pacific, Indian and Atlantic Oceans. They also understand that some eruptions occur on the sea bed. This may indicate a conception of the Middle ocean ridge in the knowledge base of the older students; but among Primary students, no-one mentions that volcanic eruptions may occur there.

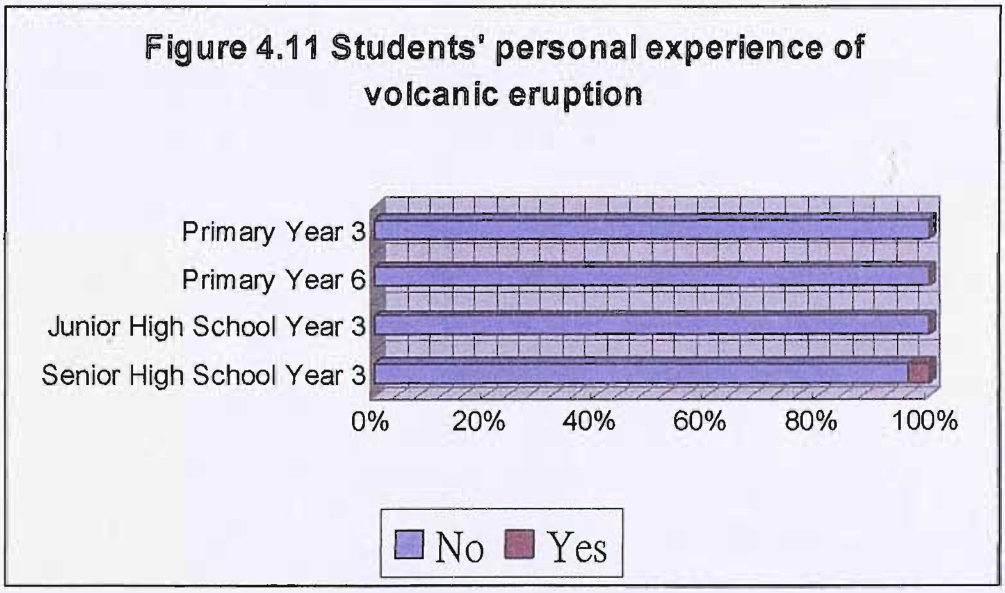
Although all the students mention where volcanic events occur on the world map, Secondary students describe them in more geological detail, whereas Primary students give more geographical detail. Students were asked to circle locations on the world map when they responded to this question. Many Primary Year 3 students could not find the relevant place/country to circle. This showed poor location conception, though knowledge can be acquired through repetition. Primary Year 6 gave a similar pattern of responses.

The average overall response for this question was 2.30, Junior and Senior high school students both with 2.36, Primary Year 6 students at 3.08, Primary Year 3 students at 1.40; this might be because Secondary students have almost all fully understood where and when volcanic eruptions occur, and upper Primary students are not able to make an opinion yet, and so employ more immature guesswork. Primary students may understand too little to be able to give more.

Table 4.11 Students' personal experience of volcanic eruption

Question 8 Have you ever experienced a volcanic eruption?	**Senior High School Year 3**	**Junior High School Year 3**	**Primary Year 6**	**Primary Year 3**	**Total**
No	24	25	25	25	99
Yes	1	0	0	0	1
Total number of responses	25	25	25	25	100

(If every child gave a single response, there would be 25 for each school year column total.)



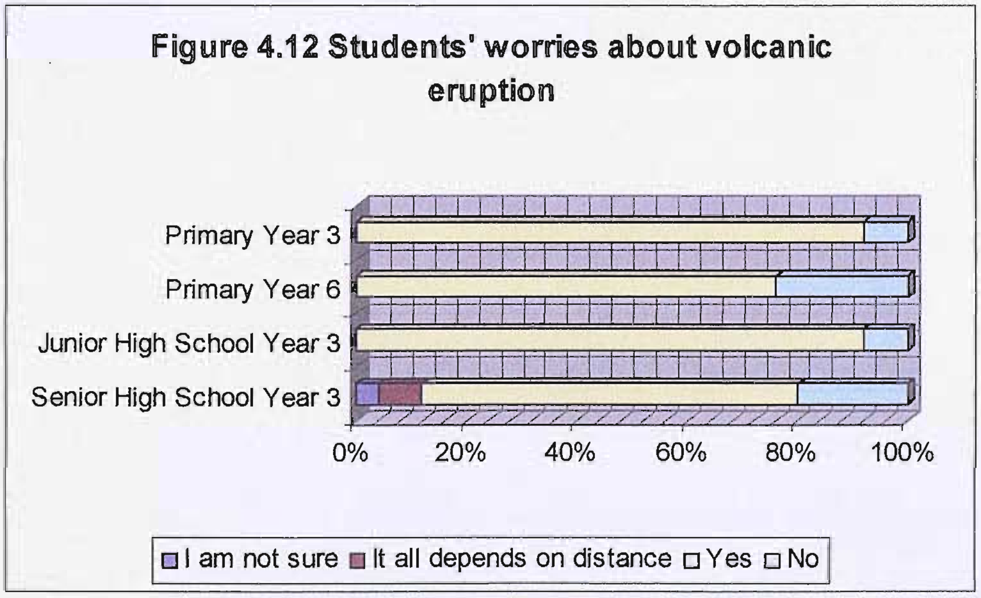
99% of students had never experienced any volcanic eruption, which might be why the definition of volcanic eruption may be different for each person. For most students, volcanic eruptions contain lava, smoke, steam, etc. One Senior level student indicated that he had experienced a muddy volcanic eruption. According to the Earth Science textbooks at Junior level, Secondary students should understand muddy volcanoes, even in the early stages of Junior high school, but it seems that the definition of volcanoes for most Secondary students is narrowly understood.

Structure and eruptional principles are basically the same in muddy volcanoes and "ordinary" volcanoes, but only 1 student had a clear idea about this. Whether students have been introduced to different types of volcanoes or not, the eruptional product still plays a key role in students' judgments regarding the identification of "real volcanoes".

Table 4.12 Students' worries about volcanic eruption

Question 9 Are you afraid of volcanic eruptions?	Senior High School Year 3	Junior High School Year 3	Primary Year 6	Primary Year 3	Total
I am not sure	1	0	0	0	1
It all depends on distance	2	0	0	0	2
Yes	17	23	19	23	82
No	5	2	6	2	15
Total number of responses	25	25	25	25	100

(If every child gave a single response, there would be 25 for each school year column total.)



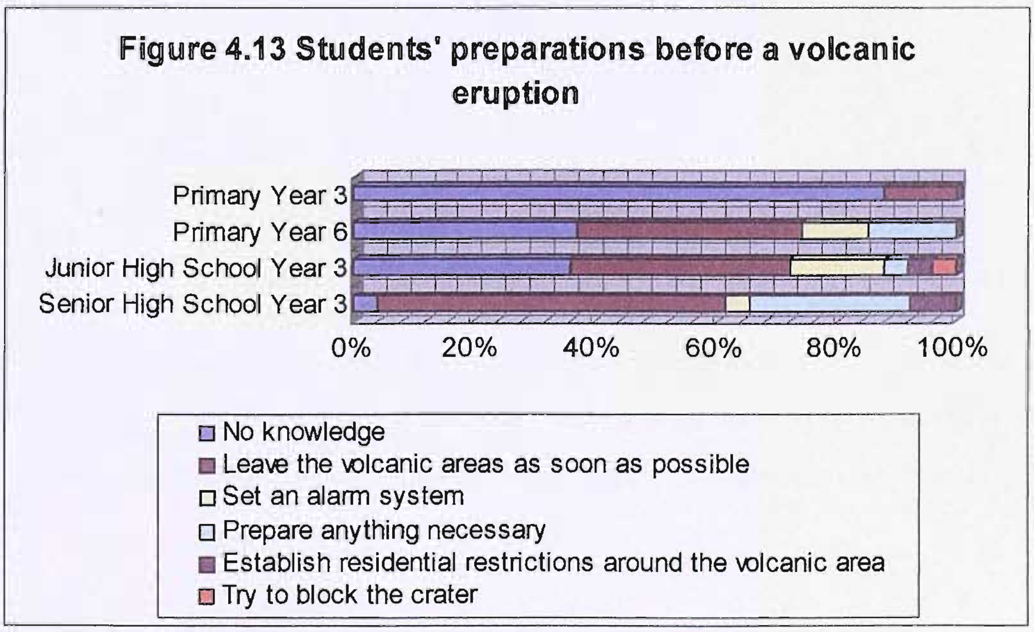
Senior level students sounded more rational than other students, giving answers beyond a simple "yes" or "no". One student, unsure of his own feelings, thought that only when people face real situations will true reactions be shown. Two Senior students considered distance. It is quite reasonable for them to think that distance may determine safety or danger, and thus be related to personal fear.

Of course, the other students were afraid of volcanic eruption, the main causes cited being heat, smoke, and other reasons relating to loss of life or injury. There is no particular pattern showing any group of students to be more afraid or less afraid of volcanic eruptions. While yes/no answers may look random, attendant explanations are not without meaning.

Table 4.13 Students' preparations before a volcanic eruption

Question 10-1 What should we/you do ***before*** a volcanic eruption?	**Senior High School Year 3**	**Junior High School Year 3**	**Primary Year 6**	**Primary Year 3**	**Total**
No knowledge	1	9	10	22	42
Leave the volcanic area as soon as possible	15	9	10	3	37
Set an alarm system	1	4	3	0	8
Prepare anything necessary	7	1	4	0	12
Establish residential restrictions around the volcanic area	2	1	0	0	3
Try to block the crater	0	1	0	0	1
Total number of responses	26	25	27	25	103

(If every child gave a single response, there would be 25 for each school year column total.)



88% of Primary Year 3 students had no knowledge about what they should do before a volcanic eruption. There might be two reasons for this. First of all, Year 3 students are too young to have experienced earthquake or know how to react. Secondly, they do not have enough background knowledge to think about it. More than half of Primary Year 6 and Junior level students seemed to show personal concern, and among Senior level students, only one had not thought through this problem yet.

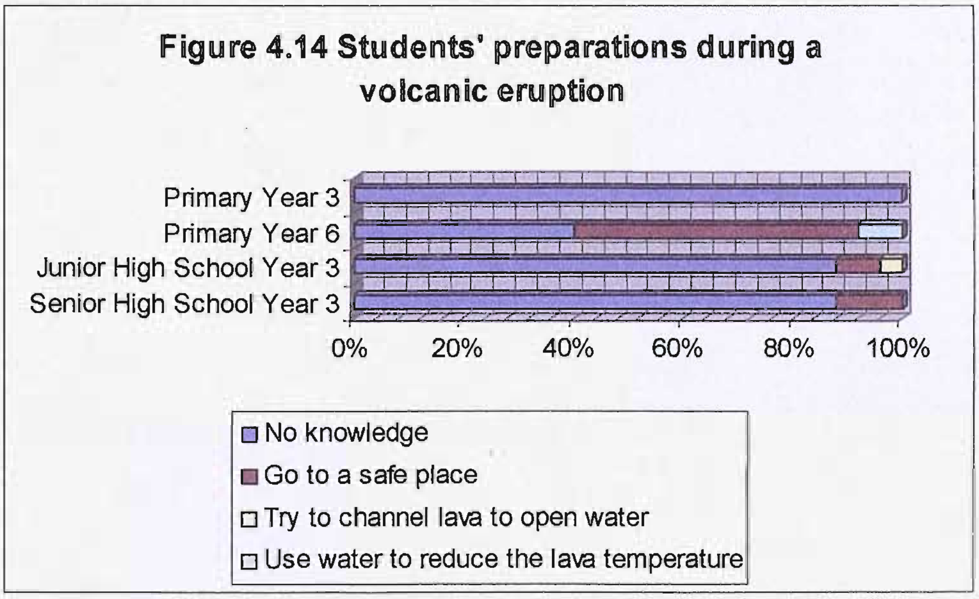
Apart from Primary Year 3 students, the majority of students understood that volcanic power is impossible to withstand; therefore, they would choose to leave the volcanic area as soon as possible. The second commonest response among High school students and upper Primary students was 'prepare as much as possible'. Primary Year 3 students seemed unaware of the possibility of an alarm system to monitor volcanic status, and neither Primary Year 3 nor Year 6 had ever had the idea of establishing a restricted residential area around volcanoes. Although Secondary students seemed to have better ideas than those at Primary level, there were still exceptions. One Junior student believed that blocking the volcanic crater could be a feasible way to prevent volcanic hazard.

There is no outstanding result for any study grade; all study levels had similar frequencies to this question, the overall average response being 1.03.

Table 4.14 Students' preparations during a volcanic eruption

Question 10-2 What should we/you do ***during*** a volcanic eruption?	**Senior High School Year 3**	**Junior High School Year 3**	**Primary Year 6**	**Primary Year 3**	**Total**
No knowledge	22	22	10	25	79
Go to a safe place	3	2	13	0	18
Try to channel lava to open water	0	1	0	0	1
Use water to reduce the lava temperature	0	0	2	0	2
Total number of responses	25	25	25	25	100

(If every child gave a single response, there would be 25 for each school year column total.)



79% of students could not indicate a proper course of action while a volcano is occurring. Primary Year 3 students fared the worse; none of them knew what to do during a volcanic eruption. But even 88% of Junior and Senior high school students did not know what to do, either!

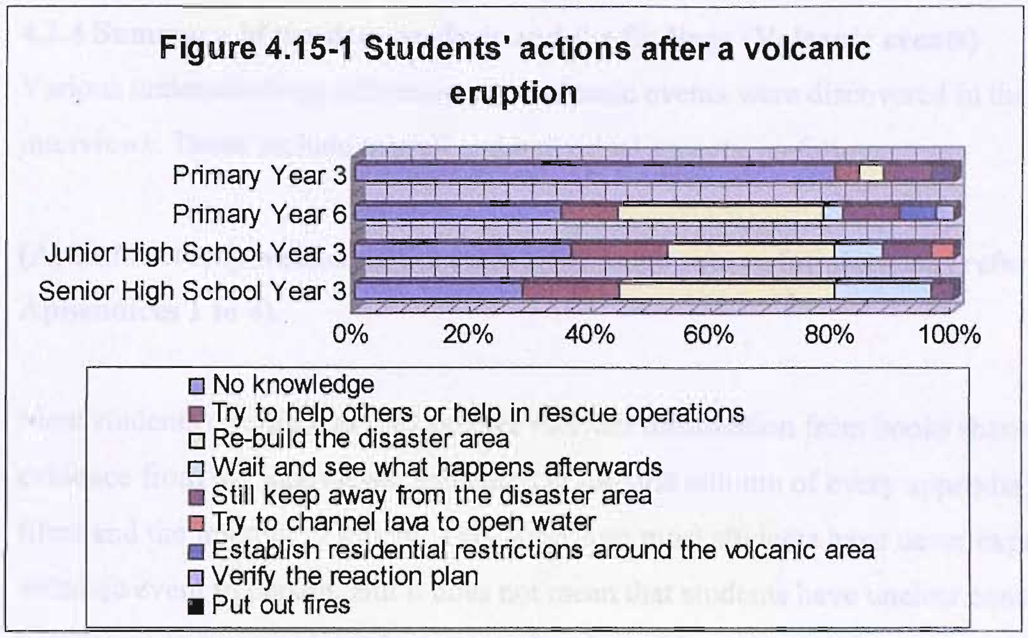
Unusually, Primary Year 6 students had the best results. The other years had more than twice the number of individuals with no knowledge. Junior Year 6 gave a correct answer over four times more than Senior High school students. Overall, 18 students mentioned going to a safe place; only 1 Junior student would try to channel lava to open water; two upper Primary students would use water to reduce the lava temperature.

It seems that most students would like to deal with eruptional events before they occur (go to a safe place, or dig a channel to lead lava to open water), and only a few students would deal with the matter after the occurrence (watering lava).

Table 4.15-1 Students' actions after a volcanic eruption

Question 10-3 What should we/you do ***after*** a volcanic eruption?	**Senior High School Year 3**	**Junior High School Year 3**	**Primary Year 6**	**Primary Year 3**	**Total**
No knowledge	7	9	11	20	47
Try to help others or help in rescue operations	4	4	3	1	12
Re-build the disaster area	9	7	11	1	28
Wait and see what happens afterwards	4	2	1	0	7
Still keep away from the disaster area	1	2	3	2	8
Try to channel lava to open water	0	1	0	0	1
Establish residential restrictions around the volcanic area	0	0	2	0	2
Verify the reaction plan	0	0	1	0	1
Put out fires	0	0	0	1	1
Total number of responses	25	25	32	25	107

(If every child gave a single response, there would be 25 for each school year column total.)



Nearly half the students could not say what to do after a volcanic eruption. Those who could tended to favour rebuilding the disaster area and trying to help others (some rescue work). Primary Year 3 students were the least able to answer this question, perhaps because they are too small to do anything.

Among students' different ideas, one appeared to be to do nothing but consult the plan, and one Junior student would try to channel lava to open water. In fact, it is very difficult to do so after a volcanic eruption.

Most students considered post-event action. Only 12% of students, mostly from Secondary level, adopted a wait-and-see policy; only 4 students still remembered setting the alarm system for the next time and to verify the reaction plan; they were all Junior and upper Primary students.

The overall average response for this question was 1.07, but only upper Primary students gave more than one reaction (1.28).

4.2.4 Summary of the data analysis and the findings (Volcanic events)

Various understandings of/reactions to volcanic events were discovered in the analysis of interviews. These include overall and individual aspects, as follow.

(A) Indirect information is the main knowledge source for students (refer to Appendices 1 to 4)

Most students declare that they receive relevant information from books (based on the evidence from the interviews, annotated in the first column of every appendix), video, films and the internet in school. This is because most students have never experienced any volcanic event in person. But it does not mean that students have unclear concepts about volcanoes. In fact, students have very clear basic ideas about volcanic events and eruptions. The general phenomena of volcanic events are well known to all the students, and it does not seem obvious that Secondary students actually have better ideas than Primary students. This is possibly because most students have already had exposure to information about volcanoes both formally, through a number of sources of information, and by extracurricular reading, and it seems that they are also influenced by informal information. For example, many students have seen the well-known American film "Volcano" of a few years ago, and it seems that almost everybody had a deep impression about what happens during a volcanic eruption.

However, students do have mixed understandings as to "What is a volcano?" It seems that definitions of volcanoes for Secondary students are more likely to focus on internal movements, while for Primary students they are more likely to focus on external features.

(a1) Students' uncertain answers (refer to Appendices 1- 4)

Students can be uncertain about the details of volcanic events. For example, many students are able to indicate lava flow as a kind of symbol of a volcanic eruption, but only some students can explain the characteristics of lava; although most students regard lava flow as a powerful hazard, because of its high temperature, it is difficult for students to present further knowledge of lava flow. Moreover, students are not clear how to react to volcanic events, with common suggestions being "set an alarm system", "leave the place", or "establish a residential restriction around the volcanic area". Very few students could fill in details on these ideas.

Although uncertain answers apply all across the study range, there are also some differences within each study level; for example, Secondary students mention that volcanic events are mainly caused by plate tectonics, yet most students do not understand exactly the mechanisms of plate tectonics, and even though one or two students mentioned heat convection as a major force in plate tectonics, there was no one able to make a link between heat convection and asthenospheric movement. It seems that students might understand that energy underground causes volcanic events to happen, but they are not sure if asthenenospheric movements are involved in volcanic events. This may explain why students did not mention hot spots in response to this question. (The places where hot spots occur usually contain frequent asthenospheric movement). In sum, Secondary students are able to describe the general situation regarding how volcanic events occur, but they have no clear idea relating to specific theories.

Primary students are also able to explain the general situation, but cannot supply reasons. For example, they understand that a volcanic event is a kind of energy release, but they have no ability to talk about why or how it is so. Many Primary students adapt other geological ideas to explain volcanic events, and although the answers are not one hundred percent correct, their explanations are not totally nonsense. A good example is of a student who believed that there must be something hitting the bottom of the ground and the "hitting power" causes volcanic events to happen. In a way, this kind of explanation sounds immature, but at least it attempts to cover some basic point. What seems to happen with Primary students is that they can identify volcanic events and have some idea about some aspects, but they are not sure which kind of more detailed explanation is correct. The uncertain answers usually relate to Type (a)+(e) (Understanding scientific concepts and interpreting correctly plus geological concepts) and Type (b)+(e) (Using scientific concepts, but incorrect/not clear scientifically, plus geological concepts). Students have already learned basic geological concepts. As I have mentioned, these geological concepts are not necessarily from school lessons or textbooks. The key point is that, when students gain knowledge outside school, they may not fully assimilate it, but they gain a strong impression about what they see in the media. This might be why they have uncertain answers. Moreover, when students receive strong impressions through the media, in many cases they would like to harmonise them with their existing knowledge (mostly about general science) to answer my questions. Therefore, although they try to answer the question from a geological point of view, sometimes their explanations are scientifically incorrect, which causes Type (b)+(e) responses (Using scientific concepts, but incorrect/not clear scientifically plus geological concepts) Of course, if their explanations are scientifically correct, this gives a Type (a)+(e) response (Understanding scientific concepts and interpreting correctly plus geological concepts). The type (b)+(e) answers indicate that students are not confident in their existing knowledge, they are not sure if their responses are correct or not. This situation reveals that students might not understand or handle what they have learned properly.

(B) The description/repetition of accepted knowledge and existing images are very effective in personal understanding

(b1) Without personal experience, students seem to regard any available information as reality (refer to Appendices 1- 4)

Many Taiwanese students have experienced earthquakes but not a volcanic event. Hence, from their accounts, it seems that almost all their knowledge is from books or film, because they refer to these rather than school information and personal experiences in their interview answers. The theoretical descriptions that they do use may sound like a copy from textbooks, but their description of volcanic landscapes seems to be more like from a TV programme or film.

Students seem to fully accept what they have read and seen from books and films, but have never experienced any volcanic event in person. Experiencing an event in person brings reality to the feeling, but students have a particular sort of knowledge or image common to most people, in this case of volcanic events.

Such students might belong to the class of Type (a)+(e) (Understanding scientific concepts and interpreting correctly plus geological concepts) or Type (c) (Lacking scientific concepts or with misconceptions). In fact, it seems that not many students with no personal experience of some particular geological event (for example, volcanic eruption), tend to belong to Type (c) (Lacking scientific concepts or with misconceptions). Most students might have correct scientific concepts, but the great difference is that these scientific concepts might contain geological concepts to a varied extent for each student; hence, they have a different understanding within Type (a)+(e) (Understanding scientific concepts and interpreting correctly plus geological concepts).

(b2) Accepted knowledge sources could affect students views in some respects (refer to Appendices 1- 4)

Not including Lower Primary level, all students favour the idea of re-building disaster areas. It seems that the idea of recovery is introduced at late Primary level; in the General Science curriculum for Primary Year 1 and Year 2, there is almost nothing referring to natural hazards and re-construction. The concept of natural hazard and re-construction is first introduced in Year 3, indirectly, and related to earthquakes. General Science Textbook 6, Chapter 6, "The power of water flow", explains the need for re-construction when rivers erode hillsides, and typhoon conditions complete the damage. The above examples are the only two sections to discuss about re-construction in Primary scientific textbooks. This might be why Primary students generally seem to have weak ideas about the concept of re-construction.

On the other hand, the Earth Science curriculum in Secondary and also the General Science curriculum in Upper Primary both build on concepts of natural hazard and reconstruction, and the students' learning seems to be reflected in their answers, with the older students more concerned with how to recover or re-build the disaster area. In this classification, most students are of Type (d) (No knowledge). It is very clear that students have completely no idea about re-building disaster areas in the case of a volcanic eruption unless they gain the relevant knowledge in school. This shows that disaster area recovery is not a common or popular idea with most students. It is more like an "after-the-event" concept rather than any traditional concept in geology. Therefore, it is less likely to be considered common sense in the students' mind, much as is the case with volcanic eruption. It seems that, if students have never experienced particular geological events, the description/repetition of accepted knowledge and existing images becomes the key element for students in piecing together a "new" and "possible" understanding.

(C) The connection between volcanic resource/energy application and daily life (refer to Appendices 1- 4)

Many students mention that volcanoes are a sort of energy/resource, and many of them believe that sulphur and terrestrial heat are very useful in daily life. For younger pupils, hot springs are often mentioned, rather than the term "terrestrial heat", and almost every student has taken a bath in hot spring water. This might suggest that, if real life experiences can be connected with scientific knowledge, students would have a clear memory and firm conceptual links, which would be a great help for students' scientific learning.

From the data, about 50% of students seem to clearly understand the difference between a natural resource and energy, and in fact, the older students do not necessarily have a better understanding of the difference than younger students. 50% is less than I expected, because students are first introduced to the ideas of resource limitations and natural energy in Primary Year 6 (General Science). It does appear, however, that both in Earth Science at Secondary level and General Science in Primary, there is no direct instruction as to what a resource is or what energy is. (Generally speaking, a resource is a kind of energy that human beings are able to use now, for example, terrestrial heat, whereas the meaning of energy is broader, which means that people might not to be able to use it today, for example, eruptional power and shaking.) So students belonging in this class are more likely to be of Type (a) (Understanding scientific concepts and with correct interpretation), Type (b) (Having some scientific concepts but with incorrect interpretation), Type (a)+(e) (Understanding scientific concepts and with correct interpretation plus geological concepts) or Type (b)+(e) (Having some scientific concepts but with incorrect interpretation plus geological concepts). This means that they may understand the relationship between natural resource/energy and geological events. However, a number of students do not have a clear understanding about what a geological resource is and what geological energy means. Although students are taught that volcanic resources/energy can be used, at least half of the students do not seem to think about it seriously. However, as mentioned earlier, it does not seem that the understanding of the difference between resource and energy is significantly related to students' age and study level. Comparing personal backgrounds, it seems to be related to individual thinking ability and knowledge sources as well.

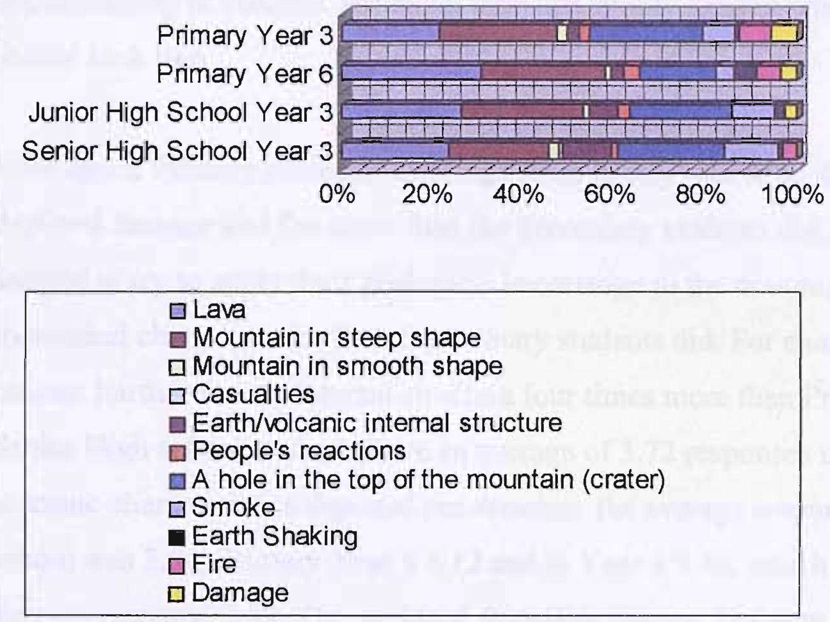
(D) Findings from pupils' drawings

Table 4.15-2 shows the number of characteristics of volcanoes that appeared in students' drawings

Students' drawings A volcano	**Senior High School Year 3**	**Junior High School Year 3**	**Primary Year 6**	**Primary Year 3**	**Total**
Lava	22	20	24	18	84
Mountain in steep shape	20	20	21	22	83
Mountain in smooth shape	2	1	1	2	6
Casualties	1	0	0	0	1
Earth/volcanic internal structure	10	5	2	2	19
People's reactions	1	2	3	2	8
A hole in the top of the mountain (crater)	22	17	13	21	73
Smoke	11	7	3	6	27
Earth Shaking	1	2	4	1	8
Fire	3	0	4	6	13
Damage	0	2	3	5	10
Total characteristics in volcano drawings	93	76	78	85	332

(If every child gave a single characteristic in drawings of volcanoes, there would be 25 for each column total.)

Figure 4.15-2 The characteristics of volcanoes that appeared in students' drawings



It seems that "Lava", "Mountain in steep shape", and "A hole in the top of mountain" are obvious characteristics from students' drawings. Moreover, students only pay very little attention to the casualties caused by volcanic events, and few students are aware of people's reactions under volcanic threat.

"Lava" and "Mountain in steep shape" are the two most popular symbols of volcanoes at all study levels. In every study grade, more than half the students represent them. Even at secondary level, the number of students reached 20. The third highest symbol for the students is "A hole in the top of mountain". In fact, from students' drawings, a volcano could be regarded as a synthetic object, synthesized by the mountain and central caves. It also seems that many students believe that all volcanoes are a kind of special mountain with a hole which allows lava and fire to come out of the mountain. The numbers of students with this idea are distributed among Secondary and Primary students. This might have two possible reasons. Firstly, for most students, because they have never seen active volcanoes in person, and the existing volcanoes in Taiwan are dormant mountains, which students might never have visited, students could have difficulties in identifying the obvious differences between ordinary mountains and volcanoes from their external appearance. Secondly, the volcanoes illustrated in the Science/Earth Science textbooks do look like ordinary mountains outside, with special internal geological structures illustrated. It is obvious, in these drawings, that a number of students do not have complete or detailed understanding of volcanic structure; they just simply present what they think a volcano should look like.

Here again, Primary students' drawings seem highly related to the sensational aspect. They depicted damage and fire more than the Secondary students did, and Secondary students seemed to try to apply their geological knowledge to the drawings, so they presented more theoretical characteristics than the Primary students did. For example Secondary students present Earth/volcanic internal structure four times more than Primary students.
Senior High school students have an average of 3.72 responses in terms of number volcanic characteristics depicted per drawing; the average response in the Junior High school was 3.04, Primary Year 6 3.12 and in Year 3 3.40, which is very close to the overall average response 3.32. The students' drawings suggest that they have general ideas about the exteriors of volcanoes; however, understanding of internal structure is quite rare; even in upper Secondary level, less than half of the students were able to indicate the general structure in their drawings.

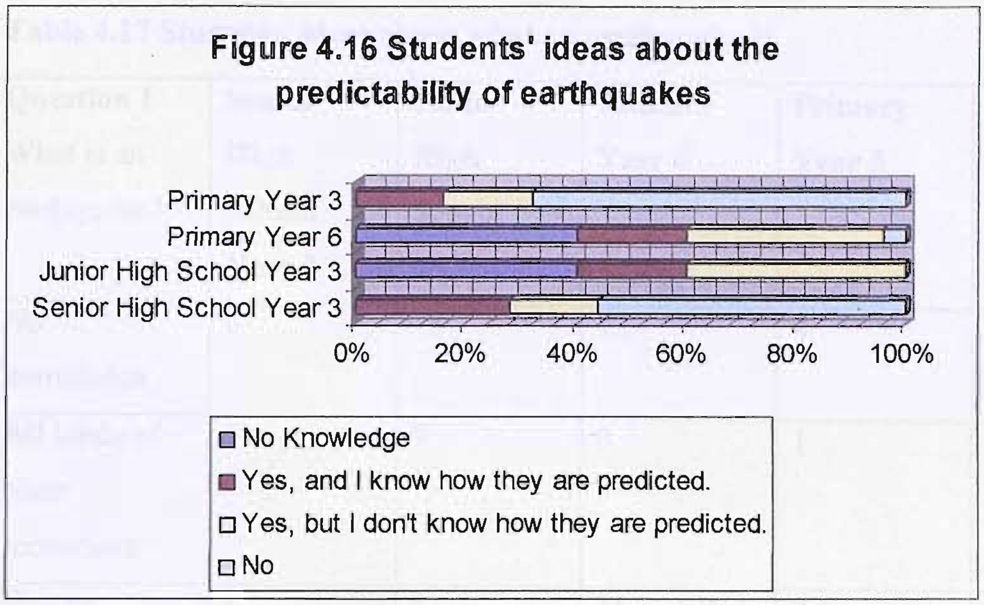
4.2.5 Data Analysis (Earthquake)

The next sections describe the results obtained from the questions about earthquakes. The interview data about Earthquake Events are available in Appendices 5 to 8.

Table 4.16 Students' ideas about the predictability of earthquakes

Question 0 Are earthquakes predictable?	**Senior High School Year 3**	**Junior High School Year 3**	**Primary Year 6**	**Primary Year 3**	**Total**
No knowledge	0	10	10	0	20
Yes, and I know how they are predicted.	7	5	5	4	21
Yes, but I don't know how they are predicted.	4	10	9	4	27
No	14	0	1	17	32
Total number of responses	25	25	25	25	100

(If every child gave a single response, there would be 25 for each school year column total.)



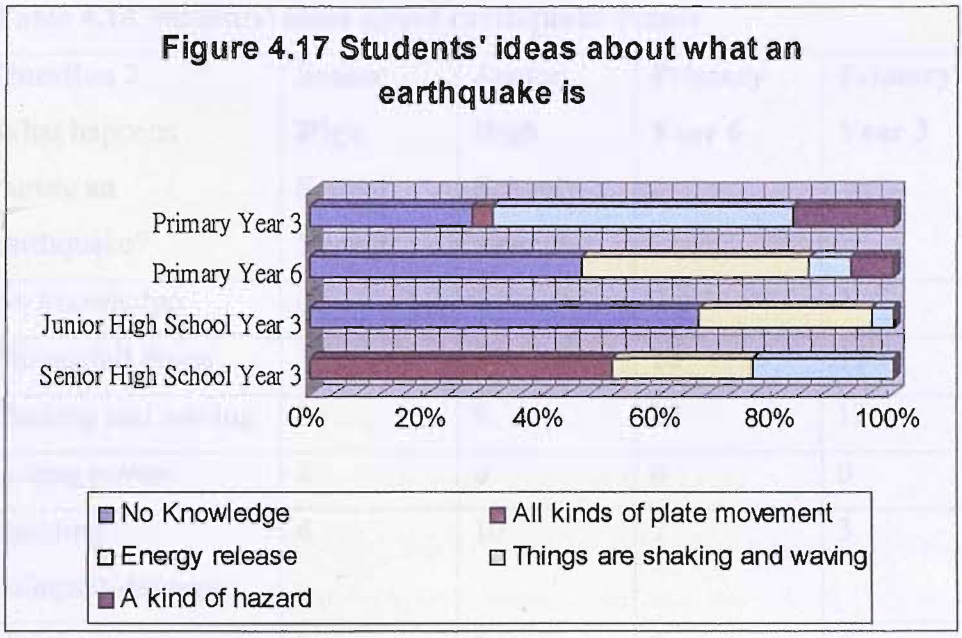
Only one third of the students know that earthquakes are not predictable, most of them being Senior and Lower Primary students. Almost half the students believe that earthquakes are predictable; however, many of these students do not have any idea about how a coming earthquake may be detected. 21 students offered an explanation as to why they believe earthquakes are predictable, but according to their explanations, more than 80% of the students only understand the general theory relating to the Earth's internal movements. They believe that the extraordinary reactions of animals should still be the best way to find out if an earthquake is going to happen nowadays. The rest of the students believe that scientists can detect earthquakes with equipment, such as seismographs, or from satellites. The greatest common factor amongst the groups of students is that they all mention that earthquake prediction is not accurate, and the warning time is too short to enable effective precautionary measures.

Junior and upper Primary students are the major groups who have completely no knowledge as to whether it is possible to detect an earthquake. This may show that students of this age have a big gap in their knowledge. Although they have very similar learning environments at school, there are still some students who cannot grasp the relevant knowledge. The average response at each study level and the average overall response are the same; there is only 1 response from each student. Most Senior students and Lower Primary students believe that earthquakes are not predictable, but Junior students and Upper Primary students have opposite ideas.

Table 4.17 Students' ideas about what an earthquake is

Question 1 What is an earthquake?	Senior High School Year 3	Junior High School Year 3	Primary Year 6	Primary Year 3	Total
No knowledge	0	18	13	8	39
All kinds of plate movement	17	0	0	1	18
Energy release	8	8	11	0	27
Things are shaking and waving.	8	1	2	15	26
A kind of hazard	0	0	2	5	7
Total number of responses	33	27	28	29	117

(If every child gave a single response, there would be 25 for each school year column total.)



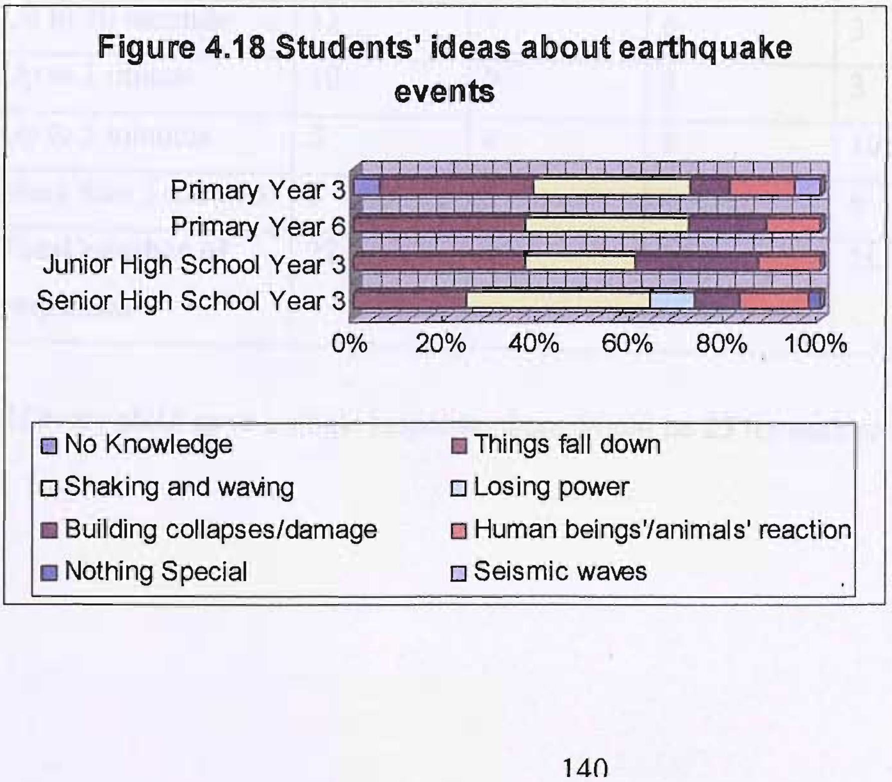
Senior high school students seem to have a confident attitude in defining what an earthquake is, and, consequently, most of them seem to be sure of the complete meaning. Although most Senior level students indicate that all kinds of plate movement (plate tectonics is still the most popular answer) are the main cause of earthquakes, amongst other students, energy release might seem to gain a more common consensus. A number of students can only express the outward situation of earthquakes, the most common being "shaking" and "waving", which are mentioned by about one third of lower primary students. However, 39 students have no idea about what an earthquake is, and none of them are Senior high school students. This might show that there is a big understanding gap between Senior level students and other students. The average response for each study level is: Senior level=1.32, Junior level=1.08, Upper Primary level=1.12, Lower Primary level=1.16. The overall average response for all students is 1.17. Although Senior students are expected to have more detailed knowledge than other students, it seems that students from Junior level, Upper Primary level and Lower Primary level have no big differences in this regard. Junior level students may have more detail than Primary students, but the variety of answers are quite similar. This shows that there is an understanding gap about general ideas of earthquakes between Junior and Senior level in particular.

The focal concept for Senior students is the theory of plate tectonics. Junior students focus on energy release (though more than half the students have no idea about this question). Upper Primary students are interested in energy release as well, and Lower Primary students focus their attention on how things shake and wave during an earthquake.

Table 4.18 Students' ideas about earthquake events

Question 2 What happens during an earthquake?	Senior High School Year 3	Junior High School Year 3	Primary Year 6	Primary Year 3	Total
No knowledge	0	0	0	2	2
Things fall down	10	14	16	12	52
Shaking and waving	16	9	15	12	52
Losing power	4	0	0	0	4
Building collapses/damage	4	10	7	3	24
Human beings'/animals' reaction	6	5	5	5	21
Nothing Special	1	0	0	0	1
Seismic waves	0	0	0	2	2
Total number of responses	41	38	43	36	158

(If every child gave a single response, there would be 25 for each school year column total.)



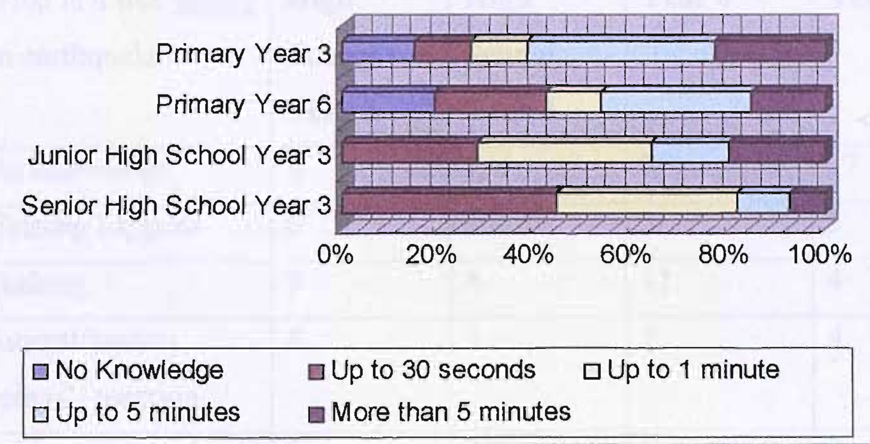
Students seem to have in common the notions of things falling down and shaking and waving, because about two thirds of responses relate to these two concepts. "Building collapse/damage" and "human beings'/animals' reaction" are less common concepts to the students. Most students have basic ideas about what happens during an earthquake, with only two Lower Primary students having no ideas about it. Students from Senior level to Lower Primary level seem to give attention equally to "human being's/animal's reaction". For this concept, there is no big difference across all study levels. The average response at each study level is: Senior level=1.64, Junior level=1.52, Upper Primary level=1.72, Lower Primary Level=1.44; the average overall response is 1.58. It seems that Senior students and Upper Primary students are more enthusiastic in expressing their opinion. Junior students are almost equivalent to the average overall response and Lower Primary students show below the average response; students from each study level all seem to focus on the same concepts which are "how things fall down to the ground" and "how things shake and wave during an earthquake".

Table 4.19 Students' ideas about the duration of earthquake events

Question 3 How long does an earthquake last?	**Senior High School Year 3**	**Junior High School Year 3**	**Primary Year 6**	**Primary Year 3**	**Total**
No knowledge	0	0	5	4	9
Up to 30 seconds	12	7	6	3	28
Up to 1 minute	10	9	3	3	25
Up to 5 minutes	3	4	8	10	25
More than 5 minutes	2	5	4	6	17
Total number of responses	27	25	26	26	104

(If every child gave a single response, there would be 25 for each school year column total.)

Figure 4.19 Students' ideas about the duration of earthquake events

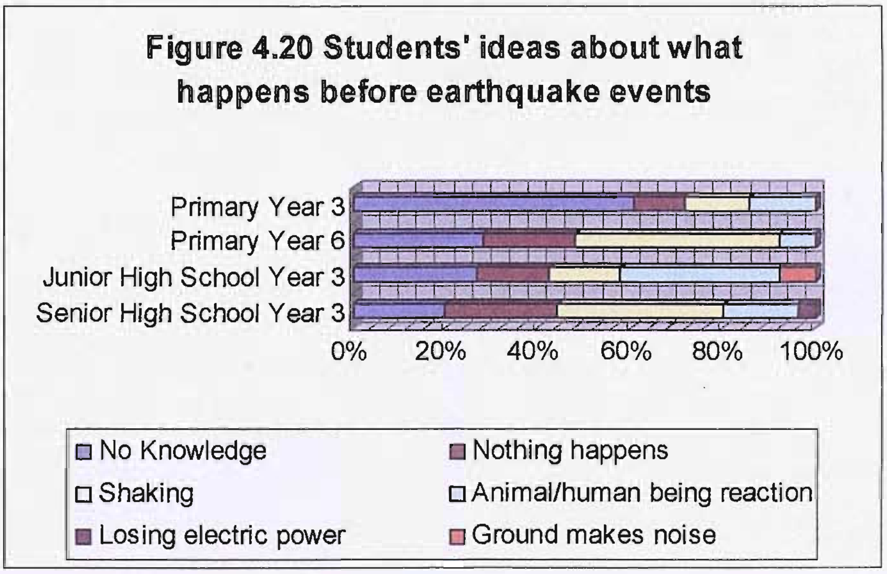


In accord with students' own experience, most have very reasonable ideas about how long an earthquake usually lasts, which is between 30 seconds and 5 minutes. About one sixth of students believed that earthquakes last longer than 5 minutes. The average response from each study level was: Senior level=1.08, Junior level=1.00, Upper Primary level=1.04, Lower Primary level=1.04 and the overall average response was 1.04 as well. In fact, students do not have so many differences in personal responses; this shows that everyone has a similar experience of earthquakes. Senior level students believe that earthquakes usually last some 30 seconds rather than any longer, whilst Junior level students think that most earthquakes last 1 minute, and both Upper and Lower Primary students believe that earthquakes usually last up to 5 minutes.

Table 4.20 Students' ideas about what happens before earthquake events

Question 4-1 What is it like *before* an earthquake?	Senior High School Year 3	Junior High School Year 3	Primary Year 6	Primary Year 3	Total
No knowledge	5	7	7	17	36
Nothing happens	6	4	5	3	18
Shaking	9	4	11	4	28
Animal/human beings' reaction	4	9	2	4	19
Losing electric power	1	0	0	0	1
Ground makes noise	0	2	0	0	2
Total number of responses	25	26	25	28	104

(If every child gave a single response, there would be 25 for each school year column total.)



More than one of third students could not answer this question, and many of them were Lower Primary students. After 'no knowledge', the most common category for students is 'shaking'. Nearly a fifth of the students thought that nothing happens in advance of an earthquake. They believe it happens suddenly, and even though there are some omens, they are very difficult to detect. Students do not deny the possibilities of earthquake omens, but they express that they are usually too mild to be noticed.

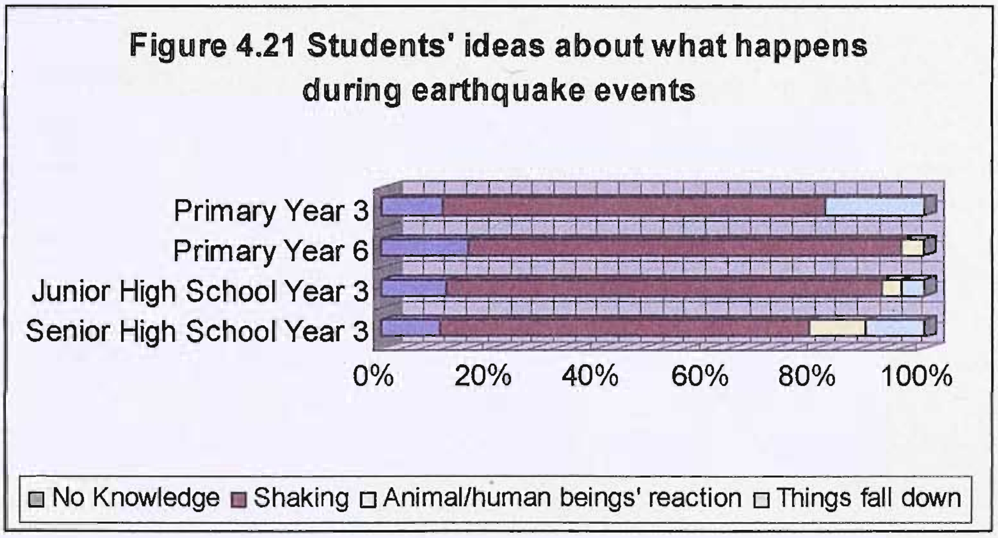
Indirect effects are always ignored at this stage. For example, only one student mentioned "losing electric power"; and two students indicated that the ground may produce noise before an earthquake occurs.

The average response for each study level was: Senior level=1.00, Junior level=1.04, Upper Primary level=1.00, Lower Primary level=1.12 and the average overall response was 1.04. From students' responses, Senior students focused on 'shaking', and the focus of Junior students was "Animal/human beings' reaction". Upper Primary students care about 'shaking' and its results very much, and Lower Primary students are not able to express much about this question.

Table 4.21 Students' ideas about what happens during earthquake events

Question 4-2 What is it like ***during*** an earthquake?	**Senior High School Year 3**	**Junior High School Year 3**	**Primary Year 6**	**Primary Year 3**	**Total**
No knowledge	3	3	4	3	13
Shaking	19	20	20	19	78
Animal/human beings' reaction	3	1	1	0	5
Things fall down	3	1	0	5	9
Total number of responses	28	25	25	27	105

(If every child gave a single response, there would be 25 for each school year column total.)



As most students' personal experience tells them, shaking is the main phenomenon during an earthquake. But there are still some students (n=13) who cannot offer any description of what it is like during an earthquake; nevertheless, this does not mean that these thirteen students have never experienced an earthquake. What it really means is that these students cannot be sure of the way to respond to this question. Most of them certainly have experienced earthquakes; some of them cannot make any response perhaps because, when earthquakes occurred, they were asleep or otherwise unaware of what was happening.

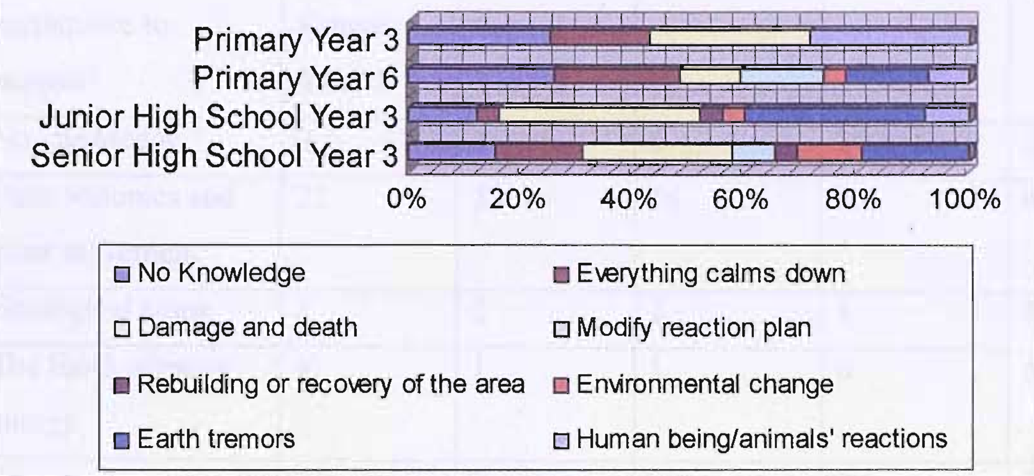
The average response for each study level was: Senior students=1.12, Junior students=1.00, Upper Primary students=1.00, Lower Primary students=1.08; and the overall average response was 1.05. For this question, most students focused strongly on "shaking", and none of the Lower Primary students noted what animal/human reactions might be during an earthquake.

Table 4.22 Students' ideas about what happens after earthquake events

Question 4-3 What is it like ***after*** an earthquake?	**Senior High School Year 3**	**Junior High School Year 3**	**Primary Year 6**	**Primary Year 3**	**Total**
No knowledge	4	3	7	7	21
Everything calms down	4	1	6	5	16
Damage and death	7	9	3	8	27
Modify reaction plan	2	0	4	0	6
Rebuilding or recovery of the area	1	1	0	0	2
Environmental change	3	1	1	0	5
Earth tremors	5	8	4	0	17
Human being/animals' reactions	0	2	2	8	12
Total number of responses	26	25	27	28	106

(If every child gave a single response, there would be 25 for each school year column total.)

Figure 4.22 Students' ideas about what happens after earthquake events



The impression of what it is like after an earthquake is largely one of "damage and death". According to students' descriptions, damage is of two types, one is natural environmental damage, which includes landslides and mud flows, the other is the damage to artificial structures, including buildings, railways and bridges. Some students also noted that Earth tremors often come soon after the main earthquake. Only Secondary students seem to have the idea of rebuilding/recovering the damaged area. Primary students have not paid attention to this aspect yet.

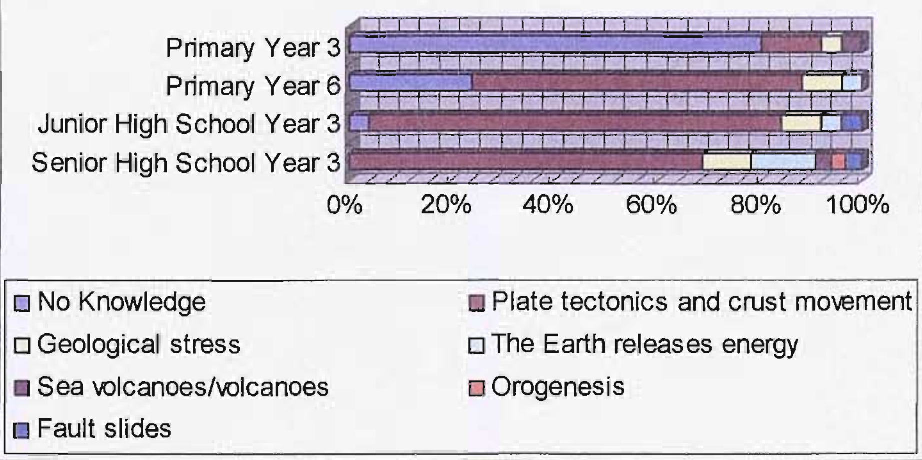
The average response for each study level was: Senior level=1.04, Junior level=1.00, Upper Primary level=1.08, Lower Primary level=1.12, and the overall average response was 1.06. Secondary students put their focus on "casualties" and subsequent earth tremors, but Upper Primary students gave attention to "what happens when everything calms down", while Lower Primary students cared very much about the "casualties". The number of students at Primary level with no knowledge about "what it is like after an earthquake" was twice the number with no knowledge at Secondary level.

Table 4.23 Students' ideas about the cause of earthquake events

Question 5 What causes an earthquake to happen?	**Senior High School Year 3**	**Junior High School Year 3**	**Primary Year 6**	**Primary Year 3**	**Total**
No knowledge	0	1	6	20	27
Plate tectonics and crust movement	22	20	16	3	61
Geological stress	3	2	2	1	8
The Earth releases energy	4	1	1	0	6
Sea volcanoes/volcanoes	1	0	0	1	2
Orogenesis	1	0	0	0	1
Fault slides	1	1	0	0	2
Total number of responses	32	25	25	25	107

(If every child gave a single response, there would be 25 for each school year column total.)

Figure 4.23 Students' ideas about the cause of earthquake events



More than half of the students thought that plate tectonics and crust movement are responsible, with Orogenesis and fault slides only mentioned by a few Secondary students.

Above Lower Primary level, students said "The Earth releases energy," though there were very few students who could elaborate on the concept. "Sea volcanoes/volcanoes" were mentioned by only one Senior student and one Lower Primary student. Upper Primary and Junior students never mentioned them.

Just over a quarter of students had completely no knowledge of what causes an earthquake, and nearly three quarters of those were at Lower Primary level. The average response for each study level was: Senior level=1.28, Junior level=1.00, Upper Primary level=1.00, and Lower Primary level=1.00; the overall average response was 1.07. Students from different study levels focused on Plate tectonics and crust movement, but most Lower Primary students were unable to identify this.

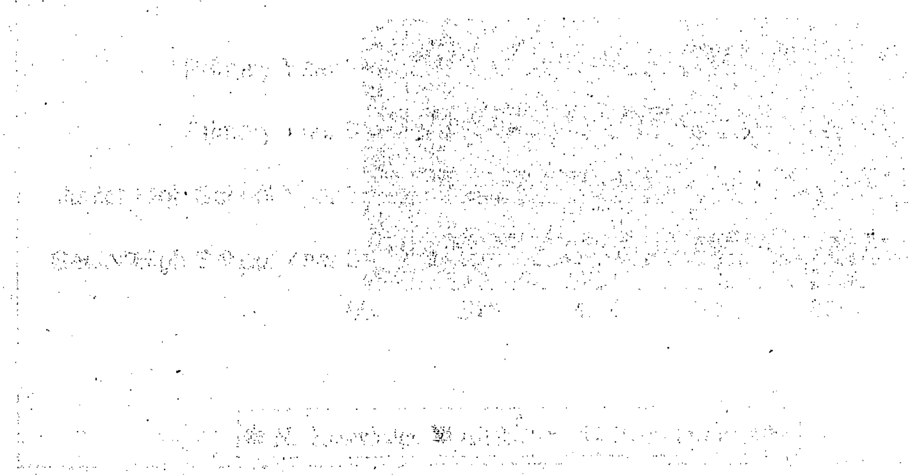


Table 4.24 Students' ideas about the frequency of unnoticed earthquakes

Question 6-1 How often does an unnoticed earthquake occur?	**Senior High School Year 3**	**Junior High School Year 3**	**Primary Year 6**	**Primary Year 3**	**Total**
No knowledge	0	3	0	0	3
All the time	25	22	25	24	96
Every few months	0	0	0	1	1
Total number of responses	25	25	25	25	100

(If every child gave a single response, there would be 25 for each school year column total.)

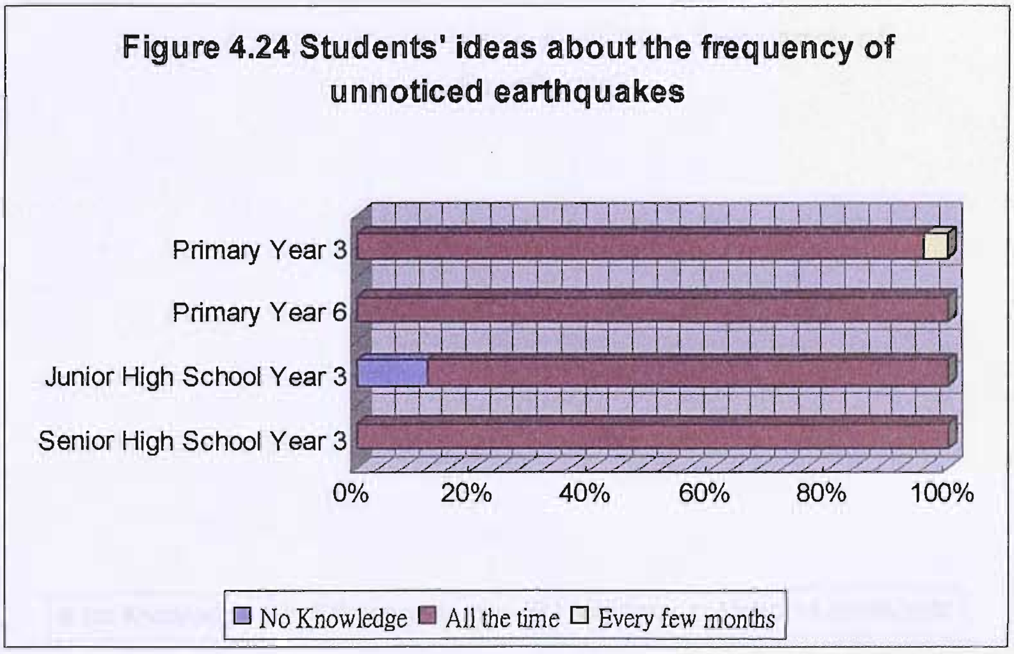
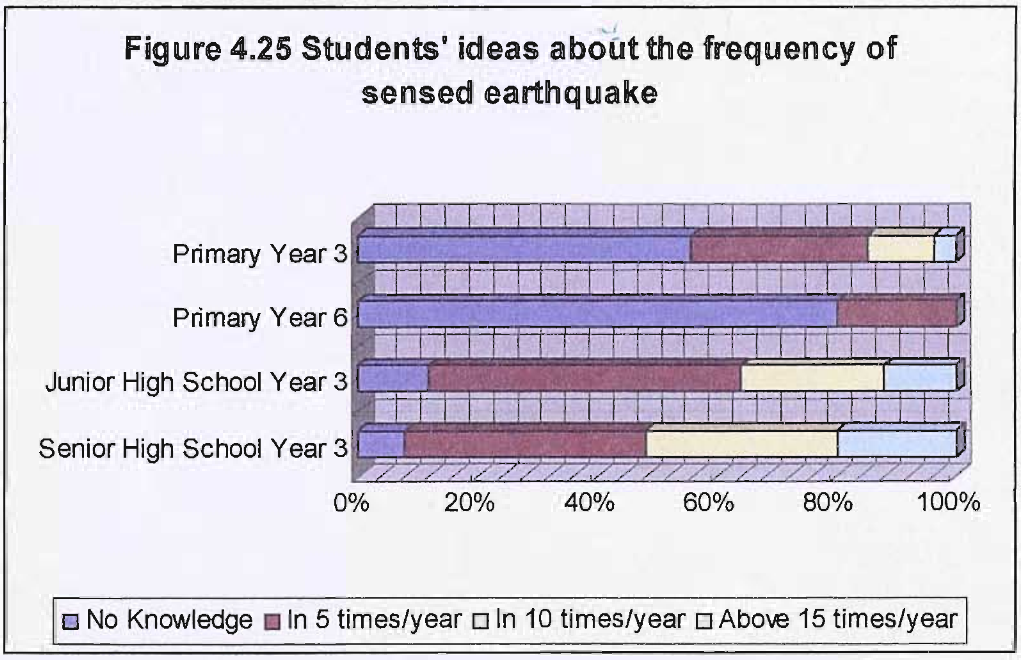


Table 4.25 Students' ideas about the frequency of sensed earthquakes

Question 6-2 How often does a detected earthquake occur?	**Senior High School Year 3**	**Junior High School Year 3**	**Primary Year6**	**Primary Year3**	**Total**
No knowledge	2	3	20	15	40
In 5 times/year	10	13	5	8	36
In 10 times/year	8	6	0	3	17
Above 15 times/year	5	3	0	1	9
Total number of response	25	25	25	27	102

(If every child gave a single response, there would be 25 for each school year column total.)



More than 90% of students believed that unnoticed earthquakes occur all the time and one third of students indicated that detected earthquakes happen about 5 times per year. Three Junior students did not express any idea about how often an unnoticed earthquake occurs, the main reason for this being that unnoticed earthquakes happen too often to be counted, according to their idea.

However, 40% of students did not know how often a detected earthquake occurs, and only a few students thought that detected earthquakes happen more than 15 times per year. The average response at each study level about unnoticed earthquakes was: Senior level=1.00, Junior level=1.00, Upper Primary level=1.00, Lower Primary level=1.00 and the overall average response=1.00. The average response for each study level about detected earthquakes was: Senior level=1.00, Junior level=1.00, Upper Primary level=1.00, Lower Primary level=1.08 and the overall average response=1.02.

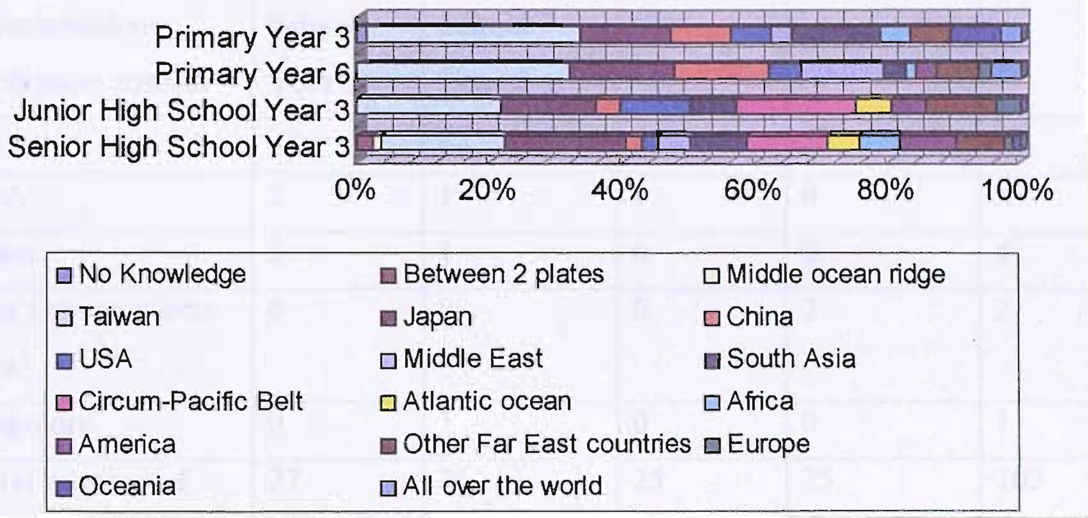
Basically, most students' understanding of earthquake frequency is in a correct and reasonable range. Only a small number of students have ideas outside the reasonable range.

Table 4.26 Students' ideas about the location of earthquakes

Question 7 Where do earthquakes occur?	**Senior High School Year 3**	**Junior High School Year 3**	**Primary Year 6**	**Primary Year 3**	**Total**
No knowledge	0	0	0	1	1
Between 2 plates	2	0	0	0	2
Middle ocean ridge	1	0	0	0	1
Taiwan	15	12	20	21	68
Japan	15	8	10	9	42
China	2	2	9	6	19
USA	2	6	3	4	15
Middle East	4	0	8	2	14
South Asia	7	4	2	9	22
Circum-Pacific Belt	10	10	0	0	20
Atlantic ocean	4	3	0	0	7
Africa	5	0	1	3	9
America	7	3	2	0	12
Other Far East countries	6	6	4	4	20
Europe	1	2	1	0	4
Oceania	1	0	0	5	6
All over the world	0	0	3	2	5
Total number of responses	82	56	63	66	267

(If every child gave a single response, there would be 25 for each school year column total.)

Figure 4.26 Students' ideas about the location of earthquakes



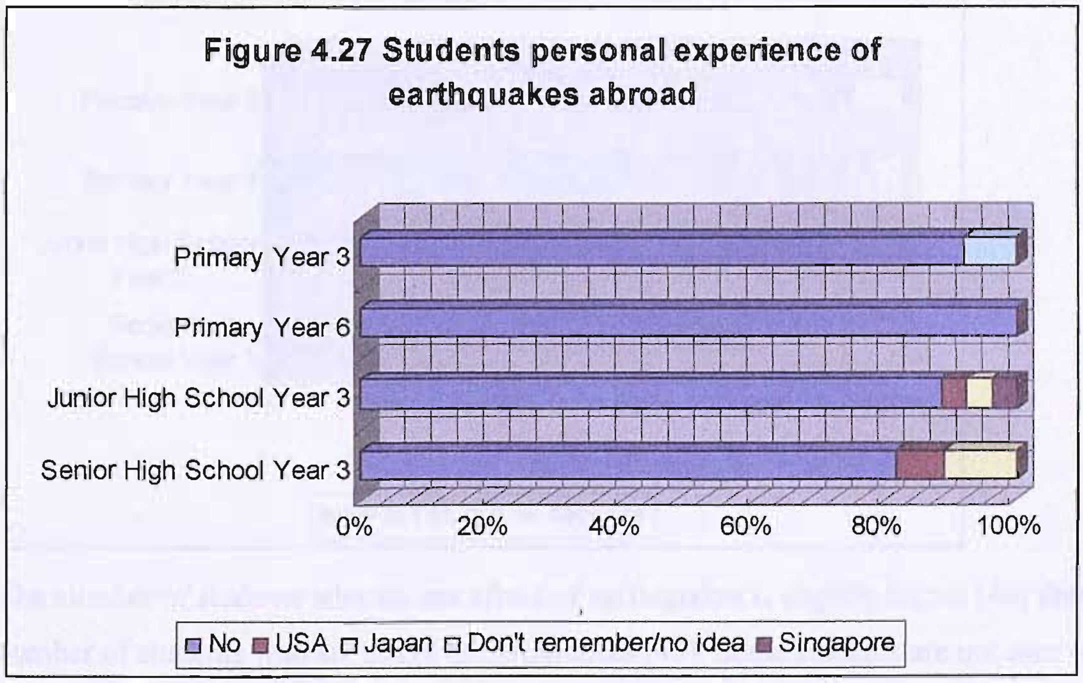
According to students' statements, Taiwan and Japan are the two most frequent places for earthquakes to occur. South Asia, the Circum-Pacific Belt and other Far East countries are the second most frequent places. Primary students have completely no idea regarding likely geological locations for earthquakes, such as the area between two plates, in the middle ocean ridge and the Circum-Pacific Belt. In fact, they do not even know these terms. Although Junior students should understand the meaning of plate and middle ocean ridge, they did not count them as places where earthquakes could occur. Five Primary students pointed out that earthquakes happen all over the world, but none of the Secondary students gave this general answer.

The average response for each study level was: Senior level=3.28, Junior level=2.24, Upper Primary level=2.52, Lower Primary level=2.64 and the overall average response=2.67. Senior students put their focus on Taiwan, Japan and the Circum-Pacific Belt, Junior students focused on the same areas; Upper Primary students gave their attention to Taiwan, Japan and China, and Lower Primary students Taiwan, Japan and South Asia. None of the Primary students thought that any European country could have a serious earthquake or ever had had a serious earthquake.

Table 4.27 Students' personal experiences of earthquakes abroad

Question 8 Have you ever experienced an earthquake abroad?	Senior High School Year 3	Junior High School Year 3	Primary Year 6	Primary Year 3	Total
No	22	23	25	23	93
USA	2	1	0	0	3
Japan	3	1	0	0	4
Don't remember/no idea	0	0	0	2	2
Singapore	0	1	0	0	1
Total number of responses	27	26	25	25	103

(If every child gave a single response, there would be 25 for each school year column total.)



Over 90% of students had only ever experienced earthquake events in Taiwan, and less than 10% had ever experienced earthquake events abroad. Students did not sense any obvious difference between earthquake events in Taiwan and other countries.

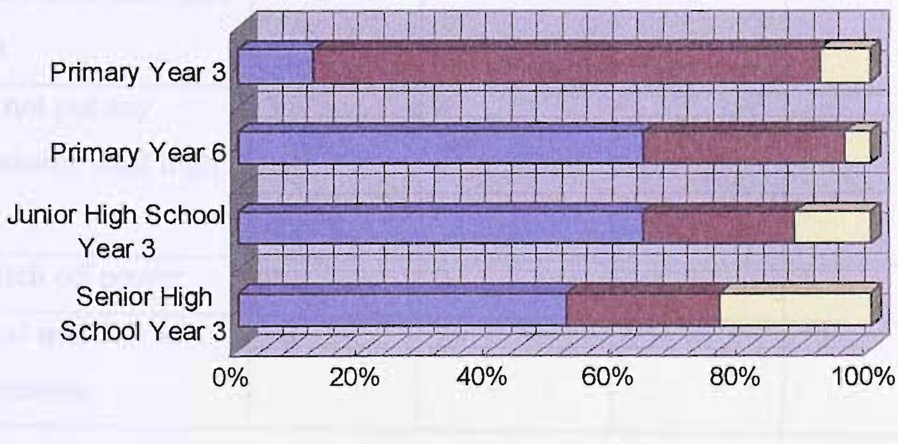
The average response for each study level was: Senior level=1.08, Junior level=1.04, Upper Primary level=1.00, Lower Primary level=1.00 and the overall average response=1.03.

Table 4.28 Students' worries about earthquakes

Question 9 Are you afraid of earthquakes?	Senior High School Year 3	Junior High School Year 3	Primary Year 6	Primary Year 3	Total
No	13	16	16	3	48
Yes	6	6	8	20	40
It all depends	6	3	1	2	12
Total number of responses	25	25	25	25	100

(If every child gave a single response, there would be 25 for each school year column total.)

Figure 4.28 Students' worries about earthquakes



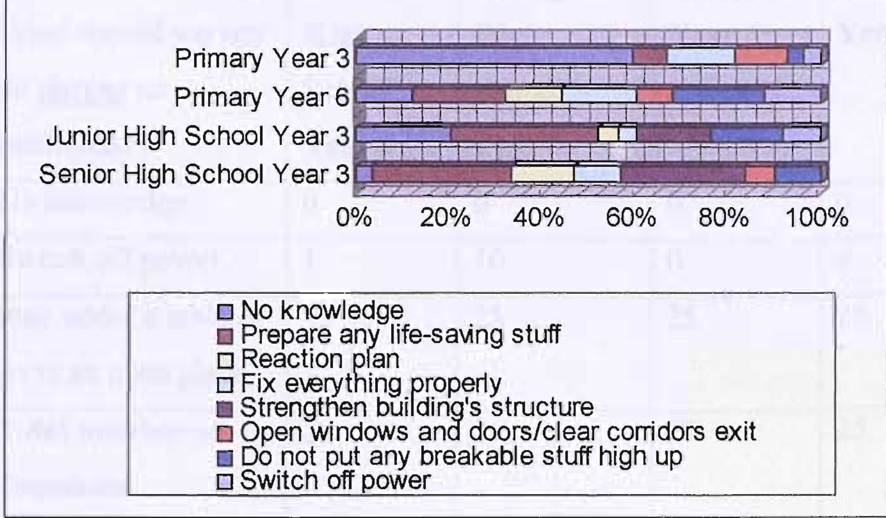
The number of students who are not afraid of earthquakes is slightly higher (48) than the number of students who are afraid of earthquakes (40). Some students are not sure whether they are really afraid of earthquakes, because they believe that it really depends on the scale of the earthquake. If it is very strong, of course they will be scared. Students who are afraid of earthquakes, truly feel that earthquakes may threaten their lives and cause physical harm. In this question, every student gave only a single response, so the overall average response was 1.00.

Table 4.29 Students' preparations before an earthquake

Question 10-1 What should we/you do ***before*** an earthquake ?	**Senior High School Year 3**	**Junior High School Year 3**	**Primary Year 6**	**Primary Year 3**	**Total**
No knowledge	1	5	3	16	25
Prepare any life-saving stuff	9	8	5	2	24
Reaction plan	4	1	3	0	8
Fix everything properly	3	1	4	4	12
Strengthen building's structure	8	4	0	0	12
Open windows and doors/clear corridors exit	2	0	2	3	7
Do not put any breakable stuff high up	3	4	5	1	13
Switch off power	0	2	3	1	6
Total number of responses	30	25	25	27	107

(If every child gave a single response, there would be 25 for each school year column total.)

Figure 4.29 Students' preparations before an earthquake



A quarter of students (25) could not tell what to do before an earthquake, and 16 of those were Lower Primary students. Almost a quarter (24) of students saw the need to prepare any kind of 'life-saving stuff', 17 of these being Secondary students. Some students cared about how to fix everything properly, strengthen building structures and avoid putting 'breakable stuff' up high (12%).

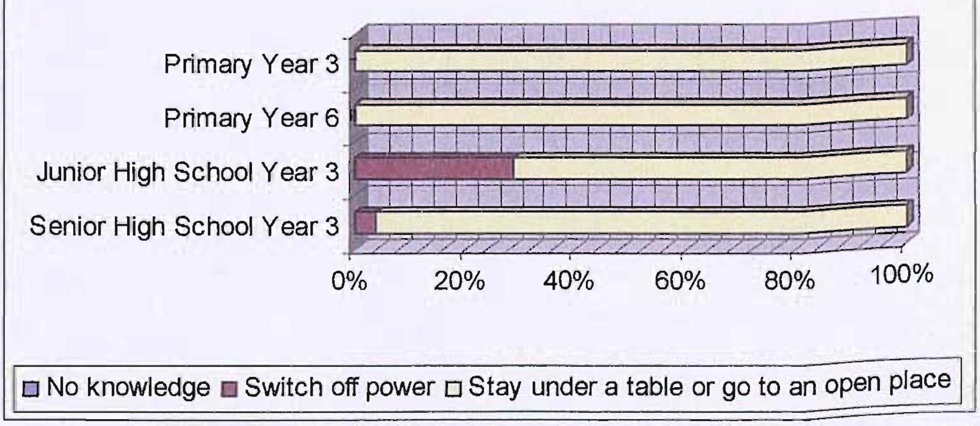
The average response for each study level was: Senior level=1.20, Junior level=1.00, Upper Primary level=1.00, Lower Primary level=1.08 and the overall average response was 1.07. A higher response might have been expected. Senior students concentrated on preparing 'life-saving stuff' and strengthening building structures. Junior students mainly focused on preparing 'life-saving stuff', and Upper Primary students had no particular focal point, but were aware of about every aspect. Lower Primary students seemed to lack the relevant knowledge to respond to this question.

Table 4.30 Students' actions during an earthquake

Question 10-2 What should we/you do ***during*** an earthquake?	**Senior High School Year 3**	**Junior High School Year 3**	**Primary Year 6**	**Primary Year 3**	**Total**
No knowledge	0	0	0	0	0
Switch off power	1	10	0	0	11
Stay under a table or go to an open place	25	25	25	25	100
Total number of responses	26	35	25	25	111

(If every child gave a single response, there would be 25 for each school year column total.)

Figure 4.30 Students' actions during an earthquake



Every student indicated that when earthquakes happen, they should stay under a table or go to an open place. Of course, these reactions are part of school training and part of their own experience. However, none of the students indicated whether it is better to stay low between two tables rather than under one table. What students say is not wrong, but students still only understand the second best way to react during an earthquake. All students have some knowledge regarding this question, which shows that every student already possesses the basics on how to react.

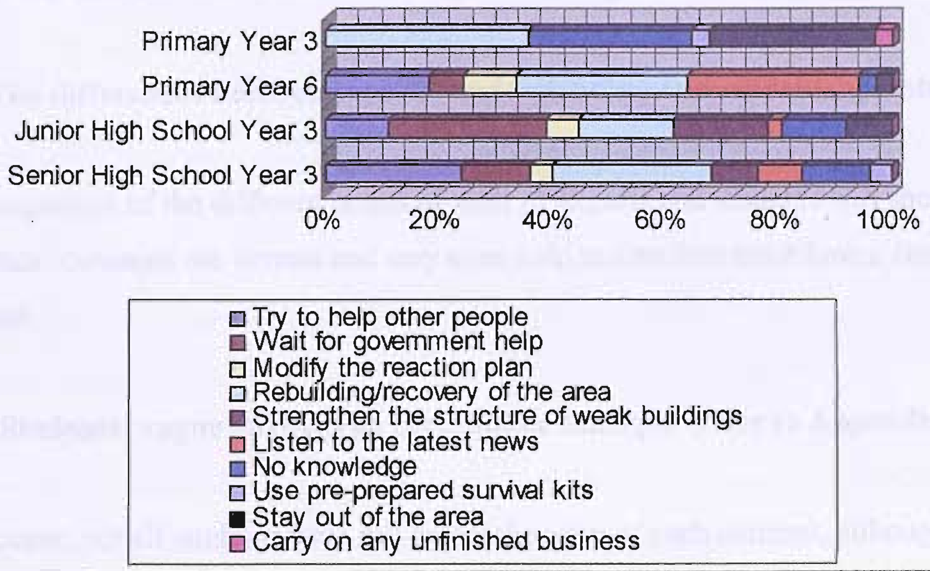
The average response for each study level was: Senior level=1.04, Junior level=1.40, Upper Primary level=1.00, Lower Primary level=1.00 and the overall average response was 1.11. All students put their first reaction as 'to stay under a table' or 'go to an open place' as soon as possible. Only 10% of students remembered to mention to switch off power.

Table 4.31-1 Students' actions after an earthquake

Question 10-3 What should we/you do ***after*** an earthquake?	**Senior High School Year 3**	**Junior High School Year 3**	**Primary Year 6**	**Primary Year 3**	**Total**
Try to help other people	6	4	6	0	16
Wait for government help	3	10	2	0	15
Modify the reaction plan	1	2	3	0	6
Rebuilding/recovery of the area	7	6	10	11	34
Strengthen the structure of weak buildings	2	6	0	0	8
Listen to the latest news	2	1	10	0	13
No knowledge	3	4	1	9	17
Use pre-prepared survival kits	1	0	0	1	2
Stay out of the area	0	3	1	9	13
Carry on any unfinished business	0	0	0	1	1
Total number of response	25	36	33	31	125

(If every child gave a single response, there would be 25 for each school year column total.)

Figure 4.31-1 Students' actions after an earthquake



More than 30% of students believed that the first priority is to rebuild/recover the area. The other main ideas include, for example, trying to help other people, waiting for government help; paying attention to the latest news and staying out of the area. These ideas were discussed by a similar number of students as a matter of first priority. Nevertheless, 17 students had no idea about how to deal with the situation after an earthquake, most of them Lower Primary students.

The average response for each study level was Senior level=1.00, Junior level=1.44, Lower Primary level=1.32, Upper Primary level=1.24 and the overall average response is 1.25. This response rate is low. Senior students and Lower Primary students focused on rebuilding/recovering the area as soon as possible; junior students believed that waiting for government help is important, and Upper Primary students revealed two obvious foci, one to try to rebuild/recover the area, the other to listen for the latest news.

4.3 Summary of the data analysis and findings (Earthquake events)

Students' understanding of/reactions to earthquake events can be divided into the two following types, which I discuss below by comparison with "expert" knowledge:

(A) The differences between experts' understanding and students' points of view.

A comparison of the different points of view of experts and students will show whether the students' concepts are correct and may even help researchers trace how a concept is formed.

(a1) Students' vague answers on earthquake concepts (refer to Appendices 5 –8)

Of course, not all students have full comprehension of each concept, although secondary students are expected to have better responses generally than primary students. In some cases, students realize what happens or how the whole earthquake event is likely to unfold, but they cannot be so sure about it, because they don't know the causes of the event. For example, when students are asked "What causes an earthquake to happen?", most students, especially those at Senior high school level are able to answer "because of plate tectonics". But, when they are asked for further information about plate tectonics, such as "What causes these plates to move against each other?", "Why do these plates keep moving?", students can only offer a vague answer. They know there is something under the plates which carries all the plates and causes them to move, yet very few students can indicate that this is called the Asthenosphere. They appear to show a reasonable understanding of the concept of the Asthenosphere, but cannot use the name. It is suprising that the term is in students' Junior and senior texts, but they seem unfamiliar with its use. It is probably because the name is also long in Taiwanese (translating literally as "soft-current-circulation"). Students understand that the moving of the earth's crust can cause earthquakes to happen, and that some kind of heat power can push all the crusts towards a cyclical movement, but only a limited number of students mentioned hot spots as one of the most important power sources of plate tectonics.

Generally speaking, students who belong to this classification are of Type (b)+(e) (Having some scientific concepts but with incorrect interpretation plus geological concepts.)

This means that they may have a general idea of the geology, but, they do not have a clear understanding or may even have a misunderstanding on some particular points.
Their abstract answers show that they have a basic conception as to how and why earthquakes occur, but they are not able to give any further explanation clearly. In other words, they may know the causes and theories, but cannot comprehend the detail. The greatest obvious disadvantage of this is that students might regard several similar concepts as one, because they have very similar results. In this case, students have difficulty distinguishing between the theory of continental drift, the theory of ocean-floor spreading and the theory of plate tectonics. Students might see only one similar result, that they cause each continent to reach its own current position. In fact, these three theories have different explanations. However, it seems that students with vague answers place more attention on the result (current status) rather than on the differences in detail between these three theories and on which particular one causes the current status. This might explain why their abstract answers match all three theories in general.

(a2) Students' guesses linking existing concepts and unclear knowledge (refer to Appendices 5 – 8).

Sometimes, when students cannot be sure of the principles behind earthquake phenomena, they may take a guess. For most Senior and Junior students, the guesses are based on existing knowledge. Students' guesses come under the four possible classifications, namely: Type (b) (Having some scientific concepts but with incorrect interpretation), Type (b)+(e) (Having some scientific concepts but with incorrect interpretation plus geological concepts), Type (b)+(f) (Having some scientific concepts but with incorrect interpretation plus non-geological concepts) and Type (c) (Lacking scientific concepts or with misconceptions). Most guesses appear to be of Type (b) (Having some scientific concepts but with incorrect interpretation.), because when students have to guess something, they may often have some sort of scientific concept, but they are not sure they have correct understanding. Therefore, the guesses might contain geological ideas or just the common scientific ideas. Of course, some students' guesses make no scientific sense (Type C); what they have in their minds are just wrong concepts.

It seems that most students can only indicate the location of earthquakes when they have read or heard the relevant information. Nevertheless, about one quarter of students are able to infer possible locations as having similar geological conditions to the locations students have already identified. Of course, most students adopt the geological conditions of Taiwan to infer other possible locations. On the one hand, the fact that students adopt the "geological conditions" of Taiwan, might indicate that they have clear geological knowledge in terms of Taiwanese earthquakes, but, on the other hand, the geological conditions in Taiwan are not the only conditions under which to measure the possibility of earthquake events, and do not apply necessarily all over the world. Some students from upper Primary level, Junior level to Senior level, indicate that Italy and Hawaii have earthquakes. A number of students believe that the earthquakes in Taiwan (mostly caused by plate tectonics and fault movements), Italy and Hawaii (caused by both volcanic eruption and plate tectonics) are caused by the same geological conditions.

However, some students have better informed guesses. They do not apply the very same detailed geological conditions of Taiwan to the rest of the world. Rather, they use the general geological conditions to infer possible locations of earthquakes elsewhere in the world. A good illustration is that, although students may not be able to identify in which part of the world the earthquakes are caused by precisely the same conditions as in Taiwan, they do know that the earthquakes in Taiwan are mostly caused by plate tectonics, and that plate tectonic movement must relate to hot spots, convergent plate boundaries and divergent plate boundaries; therefore, some students would guess a general range, such as Circum-Pacific belt, middle ocean ridge and "the boundary between two plates". This is a reasonable guess, and most students displaying this kind of inference are from Senior level, about 5% of total students.

(B) The effects of first contact knowledge

Students' first contact will be the starting point for the development of their knowledge of earthquakes. The information may come from students' family members, the media, or even comic books for younger students. The first contact knowledge seems to have a strong impact and it is also likely to guide quite directly students' subsequent ideas (Please refer to Appendices5 to 8).

(b1) Most first contact knowledge is accepted as a central thought base and school education has only a limited potential to change it (refer to Appendix 5 – 8).
More than 80% of the responses at primary level referred to a first contact knowledge source. For example, when I noted that some students were giving scientifically correct answers to some questions but not others, I explored their source of understanding. Many could give good answers based on a particular Hollywood film, "Volcano". Amongst lower Primary students, the answers were fairly skin-deep. They usually just repeat the information they have learned, and 90% of this is first contact information.

During the learning period at Primary school, students do have a chance to receive more of a general science background to earthquakes (which includes safety instructions in earthquake-reaction drills), but it is still very hard to replace the first impression in a student's mind. It is quite possible, if students' first contact knowledge is roughly correct, that this correct information can be a good base to help a student to develop further knowledge of earthquakes. But, if the first contact knowledge is generally incorrect, then it seems to become a learning obstacle (even as they start to learn the correct concepts at school). In this case, students might be of Type (a) (Understanding scientific concepts and with correct interpretation.), Type (b) (Having some scientific concepts but with incorrect interpretation.) or Type (c) (Lacking scientific concepts or with misconceptions). It all depends on what kind of concept they first contacted and which concept they naturally adopt as their central thought base.

First contact knowledge can also lead students to one-sided thinking or a lopsided view. This happens even at Junior and Senior level. For example, some secondary students mentioned that, just before an earthquake, there is some sort of "earthquake fish" that will show up, but no student can describe what an "earthquake fish" looks like, and besides they all believe that "earthquake fish" is the formal name of a particular fish. The truth is that "earthquake fish" is a general term, referring to the fact that some deep ocean fish can sense environmental change just before earthquake happens, and move to shallower water away from the danger. Consequently, this is an extraordinary warning from animals, but there is no particular fish called an "earthquake fish". Students' answers reveal that first contact knowledge might have serious deleterious effect on conceptual development. This effect could be long-lasting.

(b2) First contact knowledge acts as a temporary image only; concepts are changed by school education (refer to Appendices 5 – 8).

Some students seem to hold first contact knowledge as a temporary image, which does not exert a long-lasting or profound effect on their subsequent learning. This group of students might keep first contact knowledge as a sort of reference, but it does not mean they have already 100% accepted it.

This group of students can be compared to an artist's palette, which receives different colours (information) from different sources, but finally they are re-arranged to give new characteristic colours (concepts). This might happen more often with students who are more capable of individual thinking or who have had a broader background of knowledge; this might be because they have more relevant knowledge and more personal experience, against which to compare differing information. Most of these students are from Secondary level and they are less than 10% of total students. Students belonging to this classification are usually of Type (a)+(e) (Understanding scientific concepts and with correct interpretation plus geological concepts) or Type (b)+(e) (Having some scientific concepts but with incorrect interpretation plus geological concepts). In fact, it seems that these students are about to negotiate handling first contact knowledge and knowledge acquired subsequently at school. Hence, their scientific concepts are quite changeable.

This group of students usually has relatively complex and diverse answers, and the answers sometimes are only established under special conditions. For example, when they are asked "Are you afraid of earthquakes?", their answers are not simply "Yes" or "No" reactions; the answers are given with some elaboration, such as " If earthquakes last for a long time, I will be afraid of them. If not, I am not afraid." This may show that when they first experience an earthquake, the shaking might make them afraid for a while, but the impact cannot last in their minds forever, and afterwards they think it over or try to find more information to understand the events, eventually to make their own conclusion as to whether they need to worry about it or not. This means that the first contact (either indirect knowledge or first-hand experience) acts in their case as a temporary impact only; it does not really dominate these students' thinking, however, if they have more relevant geological concepts, they might change their thinking.

(b3) No particular central concepts are formed by first contact knowledge (refer to Appendices 5 – 8).

There is a group of around 10% of students who seem to have no particular central concepts formed or affected by first contact knowledge. This group of students range from Primary to Secondary level, and it seems that, although they might have gained some earthquake knowledge from family members, they do not really keep it in mind, and their current knowledge of earthquake events is mainly formed at school and through other media. Students who belong to this group appear not to be interested in earthquake events; therefore, the answers "I don't know", "I have no idea" or "I am not sure" are not very unusual reactions. In another words, students in this classification are mostly of Type (d) (No knowledge).

Excluding the factor of lack of interest, this group of students may indeed, however, have many correct concepts relating to each question. The reason could be because, unlike students from (b1) or (b2), there are no central concepts or beliefs from either first contact knowledge or self-developed ideas, and for that reason, they simply accept all the concepts from school teachers. And because they are not interested in earthquakes either, accordingly, there is no further motive for them to do after-class research into earthquakes by themselves. In this situation, the answers from this group of students might represent the virtual content of earthquake knowledge taught in Earth Science classes, and answers and concepts are quite similar to the standard text from Earth Science text books. At least, it might represent earthquake concepts the closest, as taught in the classroom.

(C) The effects of personal experience and thirst for relevant knowledge.

In some cases, students are really interested in earthquakes (as evidenced by their enthusiastic and detailed responses), and would like to know more about what causes them or what is their ultimate effect. It seems some students are affected by their parents being Science or Earth Science teachers in school (because in some of these cases, they have good responses), but these are not so many.

(c1) Reactions to personal experiences (refer to Appendices 5 – 8).

A number of students described indoor earthquake experiences, meaning that when earthquakes happen, the students are inside a building. There are several reactions from students, namely feeling panic, seeing the fun, and "it all depends on the situation". Students might belong to four kinds of classification, which are Type (a)+(e) (Understanding scientific concepts and with correct interpretation plus geological concepts), Type (a)+(f) (Understanding scientific concepts and with correct interpretation plus non-geological concepts), Type (b)+(e) (Having some scientific concepts but with incorrect interpretation plus geological concepts) and Type (b)+(f) (Having some scientific concepts but with incorrect interpretation plus non-geological concepts). These four types reveal that students' personal experience can cover almost every possibility except non-scientific conception and no knowledge at all.

The different reactions seem to lead students to have different attitudes towards earthquakes. Of course, the majority of students understand that an earthquake is a hazard. Students who are afraid of earthquakes (6% from Senior level, 6% from Junior level, 8% from Primary level Year 6, 20% from Primary level Year 3), pay attention to the catastrophic aspect of earthquakes, though lower Primary students have only a limited capacity to do so. They notice the power of earthquakes, and try to find out how to prevent serious harm and damage. They also care about where the active faults are in Taiwan, having questions that include: how many active faults are there in Taiwan? Where are they distributed in Taiwan? How often do they move?...etc. This group of students also focuses on the distance between the epicenters and the place where they live, although less than 5% of students understand the difference between epicenter and hypocenter. At least, it reveals that students are already aware that distance is the key point relating to damage from earthquakes. However, students do not talk much about the depth of earthquake. It seems they have not realized the effect of depth.

Students who report a feeling of "fun" about earthquake events do not claim that they think earthquake does no harm. The "fun" for them (most of the students are from upper Primary level and Junior level) is a feeling. They may not view earthquakes only from the catastrophic aspect, but focus on the feeling of it, especially the shaking phenomena; they describe the direction of shaking from the beginning to the end, and also talk about how often earth tremors happen after main earthquakes. This group of students describes earthquakes in a physical sense and in terms of feeling, more than from an academic viewpoint. It is also possible that parents make their young children laugh at the event in order to avoid their panic and distress.

Students whose answers are "it all depends on the situation" mostly do not pay much attention to earthquakes, but seem to feel that they occur like "rain"; it is not a question of being afraid or not afraid, when it happens. These students just try to do what they can do best at that moment, and they do not think that earthquakes will become a big worry in their daily life.

(c2) Motivation or thirst for relevant knowledge (refer to Appendices 5 – 8).
Students' motivation usually stems from a sensitivity about crisis events or their curiosity about them. Most students have both, to some degree, but perhaps younger students have more curiosity and older students more sensitivity. Students belonging to this class are usually Type (a)+(f) (Understanding scientific concepts and with correct interpretation plus non-geological concepts.). This is presumably because the motivation involves mostly preparation work (such as of aid kits, water, food) and dealing with the disaster afterwards (such as contact with family, checking everything in the affected zone). These factors are outside geology.

Senior and Junior students already have a better understanding of earthquakes, generally, and they have gained more and better background knowledge with each earthquake experienced. For that reason, Secondary students might be more aware of the potential risks than Primary students. Some potential risks are hard to find solutions to in the short term, but there are important and critical points; for example, in a very limited reaction time and limited space, what are the items most necessary for everyone to carry while an earthquake is happening? Many Secondary students indicate water, food, a torch, medicine and a First Aid kit. These are all correct, but which is the most important? This seems like a new concept for most Secondary students. Again, what should we/you do after an earthquake? Help other people? Leave the area as soon as possible? Contact family? Modify the plan for emergency action? Secondary students have very different ideas and they have very strong points to support their ideas, which shows that their motivation and the thirst for relevant knowledge have already developed considerably. They have already understood the basic concepts and principles of earthquakes, and they are approaching a more thoughtful and thorough consideration of earthquake events.

It seems that Primary students are not yet equipped to understand most phenomena occurring in an earthquake, but as many questions arise, their curiosity increases. The most direct and common way for them to satisfy their curiosity is to question their teachers or parents, and it seems that many Primary students are keen to do so.

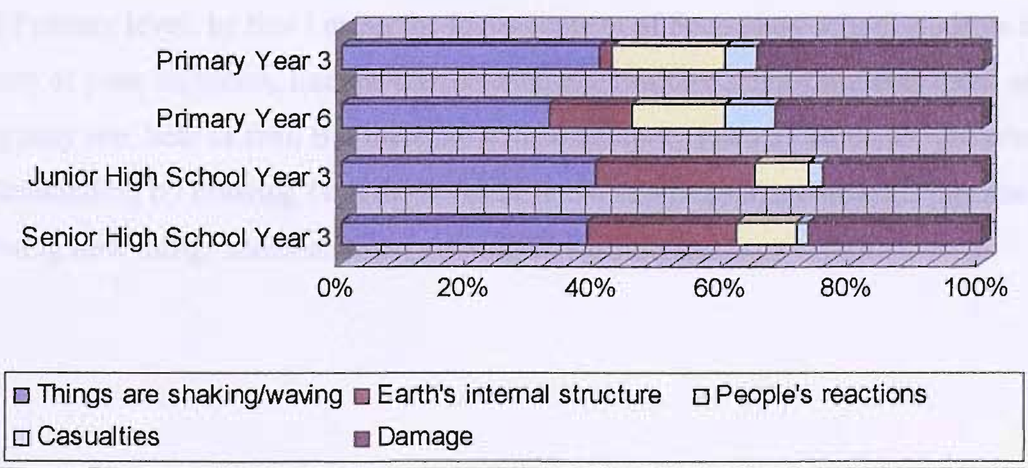
(D) Findings from pupils' drawings

Table 4.31-2 shows the number of characteristics of earthquakes that appeared in students' drawings

Students' drawings An earthquake	Senior High School Year 3	Junior High School Year 3	Primary Year 6	Primary Year 3	Total
Things are shaking/waving.	20	19	20	23	82
Earth's internal structure	12	12	8	1	33
People's reactions	5	4	9	10	28
Casualties	1	1	5	3	10
Damage	14	12	20	20	66
Total characteristics in earthquake drawings	52	48	62	57	219

(If every child gave a single characteristic in drawings of earthquakes, there would be 25 for each column total in each year.)

Figure 4.31-2 The characteristics of earthquakes that appeared in students' drawings



It seems that "Things are shaking/waving" and "Damage" are the two most common characteristics of earthquake events from students' drawings, making up more than two-thirds of the total.

Almost 50% of Secondary school students referred to the Earth's internal structure in their drawings, and these drawings show detailed understanding as to what is definitely the relationship between an earthquake and the Earth's internal structure. Most of them seemed to have a complete understanding of what an earthquake is. On the other hand, only 9 Primary school students showed their understanding of the Earth's internal structure in the drawings, although this should not be an unexpected result. However, the gap seems big between Primary Year 3 and Year 6 students. In other words, Primary students might make obvious progress in understanding the Earth's internal structure between Year 4 and Year 6. A number of students could only express the outward manifestation of earthquakes, the most common being "damage" and "people's reactions". Almost four-fifths of Primary school students drew the "damage" and half the students drew about "people's reactions". This might suggest that the sensational aspects have a huge impact on most young children. The average response for each study level is: Senior level=2.08 characteristics depicted, Junior level=1.92, Upper Primary level=2.48, Lower Primary level=2.28, the overall average response of all students being 2.19. Although Senior students are expected to draw more detail than other students, it seems that students from the Upper Primary and Lower Primary levels have more expression in their drawings. The Secondary students may draw more detail than Primary students, but the variety of characteristics are quite similar. This shows that there might be an understanding gap about internal/external Earth structure and sensational/theoretical differences between Secondary and Primary level; by that I mean the focus concept of Secondary school students is the theory of plate tectonics, internal movements, etc. Primary school students focus on what they may see, hear or feel. But there are still some upper Primary students who reveal an understanding by drawing fault movements, and a few Secondary students pay attention to drawing how things shake and wave during an earthquake.

4.4 Further/Combined Questions

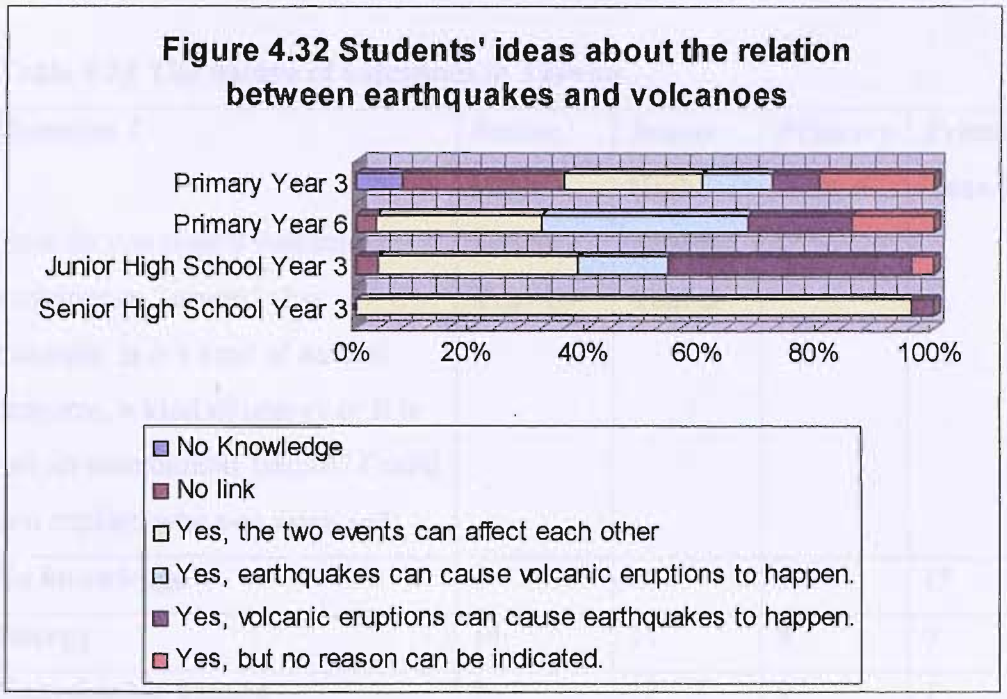
For the interview data about Further/Combined Events, please refer to Appendices 9 to 12. This section deals with students' understanding about the possible links between earthquakes and volcanic events and also reports students' understanding about volcanoes and earthquakes in Taiwan.

As these questions were presented together in the interview, they are reported together below, but summary of findings from the further/combined question is in the next section (4.3).

Table 4.32 Students' ideas about the relation between earthquakes and volcanoes

Question 1 Are earthquakes and volcanoes linked in any way? And could you tell me the reason(s).	**Senior High School Year 3**	**Junior High School Year 3**	**Primary Year 6**	**Primary Year 3**	**Total**
No knowledge	0	0	0	2	2
No link	0	1	1	7	9
Yes, the two events can affect each other.	24	9	8	6	47
Yes, earthquakes can cause volcanic eruptions to happen.	0	4	10	3	17
Yes, volcanic eruptions can cause earthquakes to happen.	1	11	5	2	19
Yes, but no reason can be indicated.	0	1	4	5	10
Total number of responses	25	26	28	25	104

(If every child gave a single response, there would be 25 for each school year column total.)



Most students have an idea about the link between volcanoes and earthquakes. Only two lower Year 3 students had completely no idea about it. All Senior students see a link between earthquakes and volcanic events, only one of whom stated that volcanoes might cause earthquakes but not vice versa. All but one Junior High school student also saw a link, with more believing that volcanoes could cause earthquakes, while among the same number of Primary Year 6 students (96%), more thought that the cause was the other way round (earthquakes cause volcanic events). In contrast, more than a third of Primary Year 3 students saw no link or had no knowledge.

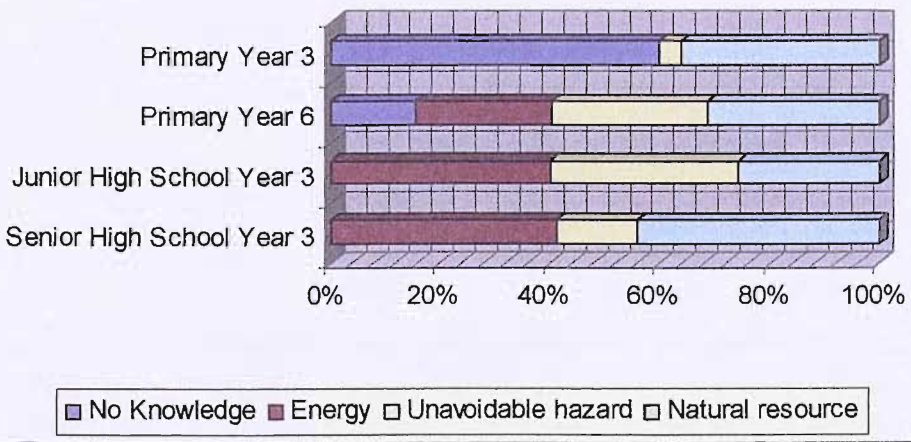
The average response at each study level was: Senior level=1.00, Junior level=1.04, Upper Primary level=1.12, Lower Primary level=1.00; the overall average response was: 1.04. Basically, the majority of students believe that there must be some link between earthquakes and volcanoes, but only a few students were able to explain how and why, which again seems to suggest a rough grasp of the scientific background but a lack of detailed scientific knowledge, or a superficial acquaintance with the geological theory involved.

Table 4.33 The nature of volcanoes in Taiwan

Question 2 How do you regard volcanic activities in Taiwan? (For example: is it a kind of natural resource, a kind of energy or it is just an unavoidable hazard? Could you explain why you think so?)	Senior High School Year 3	Junior High School Year 3	Primary Year 6	Primary Year 3	Total
No knowledge	0	0	5	15	20
Energy	14	14	8	0	36
Unavoidable hazard	5	12	9	1	27
Natural resource	15	9	10	9	43
Total number of responses	34	35	32	25	126

(If every child gave a single response, there would be 25 for each school year column total.)

Figure 4.33 The nature of volcanoes in Taiwan



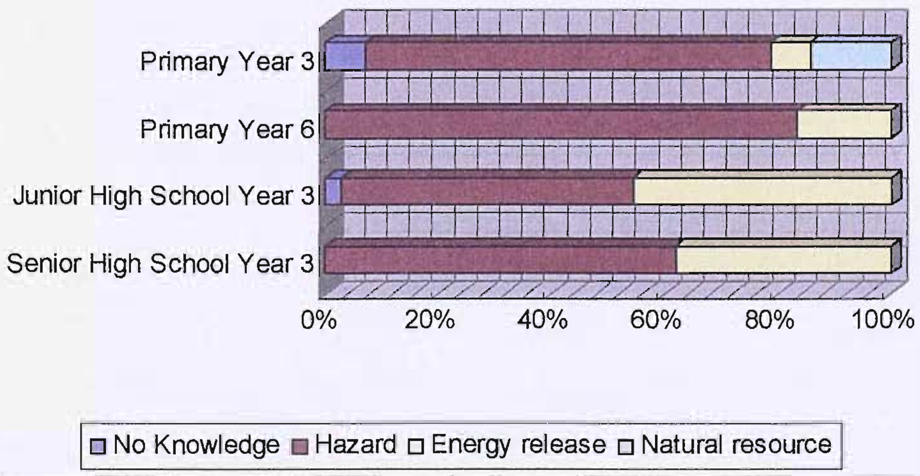
A little less than half of the students believe that volcanoes are a kind of natural resource, and more than a third of them believe that it is also a kind of energy. Senior students regard them equally as energy and a resource, and more Junior students indicated that volcanic eruptions are an unavoidable hazard. A 'natural resource' is the response slightly preferred by Upper Primary students, with 60% of Lower Primary students having no knowledge. The average response at each study level was higher than usual: Senior level=1.36, Junior level=1.40, Upper Primary level=1.28 and Lower Primary=1.00; the overall average response was 1.26. It seems that Senior and Upper Primary students focus more on volcanoes as a natural resource, while Junior students focus on the idea of energy and hazard.

Table 4.34 The nature of earthquakes in Taiwan

Question 3 How do you regard earthquakes in Taiwan? (for example: Is this a natural hazard or a necessary energy release?)	Senior High School Year 3	Junior High School Year 3	Primary Year 6	Primary Year 3	Total
No knowledge	0	1	0	2	3
Hazard	21	18	25	20	84
Energy release	13	16	5	2	36
Natural resource	0	0	0	4	4
Total number of responses	34	35	30	28	127

(If every child gave a single response, there would be 25 for each school year column total.)

Figure 4.34 The natural of earthquakes in Taiwan



With the expection of a few Primary Year 3 students, all students see earthquakes as not being a resource, and the great majority consider them as a hazard. Just over a third of students see earthquakes as a kind of energy release, the great majority of them being secondary students. At Upper Primary level, every student mentioned that earthquakes are hazards, but only five of them were able to indicate anything relating to energy.

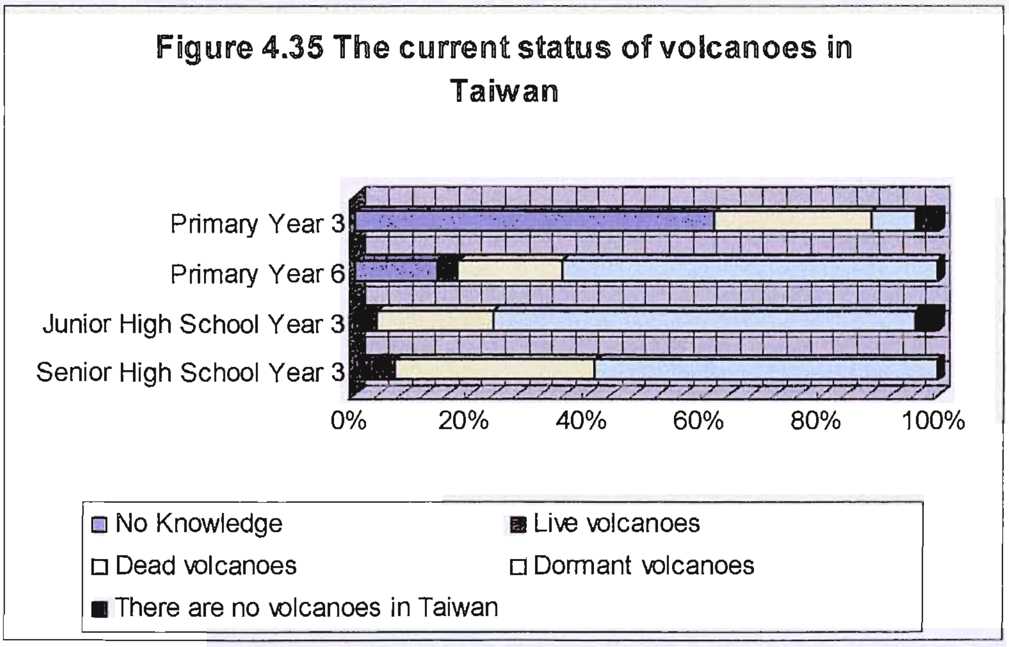
The average response at each study level was: Senior level=1.36, Junior level=1.40, Upper Primary level=1.20, Lower Primary level=1.12. The overall average response was1.27. Better understanding about earthquake events might begin at Upper Primary level.

The results seem again to suggest that it is only from upper Primary onwards that students start to get a "scientific" and well-informed conceptual background to their understanding.

Table 4.35 The current status of volcanoes in Taiwan

Question 4 How do you think of the current status of volcano in Taiwan?	Senior High School Year 3	Junior High School Year 3	Primary Year 6	Primary Year 3	Total
No knowledge	0	0	4	16	20
Live volcanoes	2	1	1	0	4
Dead volcanoes	10	5	5	7	27
Dormant volcanoes	17	18	18	2	55
There are no volcanoes in Taiwan	0	1	0	1	2
Total number of response	29	25	28	26	108

(If every child gave a single response, there would be 25 for each school year column total.)



Just over half of the students believe that the current status of volcanoes in Taiwan is dormant, and just over one quarter of the students think that the volcanoes in Taiwan are already extinct (dead). However, one Junior student and another Lower Primary student believe that there are no volcanoes in Taiwan, while a few students indicated that there are some live volcanoes in Taiwan. Some of them regard mud volcanoes as live volcanoes. As the total number of responses is 108, a few students must believe that there is a mix of live/dead/dormant volcanoes in Taiwan.

The average response at each study level was: Senior level=1.16, Junior level=1.00, Upper Primary level=1.12, Lower Primary level=1.04, and the overall average level was 1.08. It seems that personal ideas regarding this question are quite individually developed, which does not mean however that the higher study level has more responses than the lower study level. Secondary students do seem to understand that there are no completely dead volcanoes in the world.

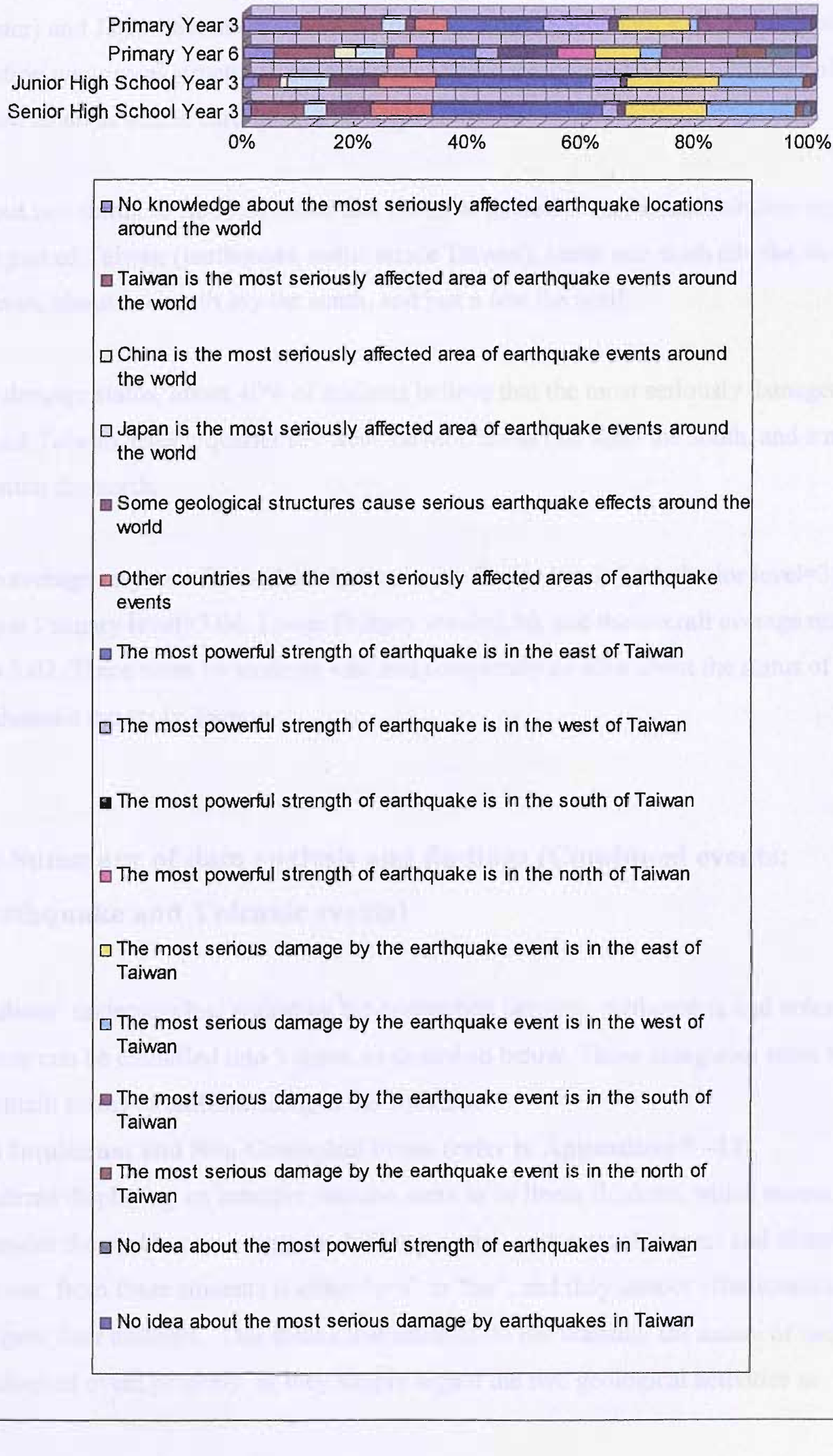
Table 4.36 The current status of earthquakes in Taiwan and around the world

Question 5 How do you think of the status of earthquake in Taiwan and around the world?	Senior High School Year 3	Junior High School Year 3	Primary Year 6	Primary Year 3	Total
No knowledge about the most seriously affected earthquake locations around the world	1	2	4	7	14
Taiwan is the most seriously affected area of earthquake events around the world.	7	3	8	10	28
China is the most seriously affected area of earthquake events around the world.	0	1	3	0	4
Japan is the most seriously affected area of earthquake events around the world.	3	6	4	3	16
Some geological structures cause serious earthquake effects around the world.	6	7	1	1	15
Other countries have the most seriously affected areas of earthquake events	8	8	3	4	23
The most powerful *strength* of earthquake is in the east of Taiwan.	23	22	8	12	65
The most powerful *strength* of earthquake is in the west of Taiwan.	2	4	3	8	17
The most powerful *strength* of earthquake is in the south of Taiwan.	1	1	8	1	11
The most powerful *strength* of earthquake is in the north of Taiwan.	0	0	5	0	5
The most serious *damage* by earthquake event is in the east of Taiwan.	11	13	6	9	39
The most serious *damage* by earthquake event is in the west of Taiwan.	12	12	3	1	28
The most serious *damage* by earthquake event is in the south of Taiwan.	0	0	10	7	17

The most serious *damage* by earthquake event is in the north of Taiwan.	1	1	4	0	6.
No idea about the most powerful *strength* of earthquakes in Taiwan	1	0	4	0	5
No idea about the most serious *damage* by earthquakes in Taiwan	0	0	2	7	9
Total number of responses	76	80	76	70	302

(If every child gave a single response, there would be 25 for each school year column total.)

Figure 4.36 The current status of earthquakes in Taiwan and around the world



About one seventh of students were not able to describe the status of earthquake events around the world. Taiwan was the most popular choice for the most serious area for earthquake events (over a quarter of students), followed by other countries (just under a quarter) and Japan (about one sixth of students). Some Secondary students were able to mention geological structures, such as the middle ocean ridge and the boundary of two plates, as areas where earthquakes usually occur.

About two thirds of students stated that the most powerful earthquakes always occur in the east part of Taiwan (earthquake status inside Taiwan), about one sixth cite the west part of Taiwan, about one tenth say the south, and just a few the north.

For damage status, about 40% of students believe that the most seriously damaged area is in east Taiwan, over a quarter say west Taiwan, about one sixth the south, and a minority mention the north.

The average response for each study level was: Senior level=3.04, Junior level=3.20, Upper Primary level=3.04, Lower Primary level=2.80, and the overall average response was 3.02. There were 14 students who had completely no idea about the status of earthquake events in Taiwan.

4.5 Summary of data analysis and findings (Combined events: Earthquake and Volcanic events)

Students' understanding regarding the connection between earthquakes and volcanic events can be classified into 3 types, as described below. These categories seem to describe the main forms of understanding to the students.

(A) Intuitional and Non-Geological Sense (refer to Appendices 9 –12)

Students displaying an intuitive reaction seem to be linear thinkers, which means that they consider the problem in a singular thinking model, with a single aspect and direction. The answer from these students is either "yes" or "no", and they cannot offer reasons to support their answers. This means that students do not consider the nature of each geological event properly, or they simply regard the two geological activities as unavoidable hazards, failing to think about any connective factors. This class is mostly Type (a)+(f) (Understanding scientific concepts and with correct interpretation plus non-geological concepts) and Type (c) (Lacking scientific concepts or with misconceptions). Students who belong to this classification seem to rely very much on their intuition.

Students with linear reactions seem to regard volcanic events and earthquakes as singular, unrelated events. Students who hold this kind of idea usually focus on how to deal with these hazards rather than to understand what is happening inside the Earth. Some Secondary students do possess a basic knowledge of earthquake and volcanic events, but they may still believe that there is no inevitable link between them, unless they occur at the same time regularly, which means that they need regular evidence to prove it.

In other words, such students may have many reasons to deny or confirm the relationship between earthquake and volcanic events, but tend to respond from an intuitional sense. They may think about each geological event but they do not usually consider the possibilities of a link between the two areas of their knowledge. No matter what kind of answers they provide, these students are usually unable to provide any example as support for their position. Normally they give answers just because they "feel" that way. This sort of learning cannot be regarded as successful understanding, because, although they might be able to talk about the geological phenomena, they have no ability to encapsulate their understanding. A successful learner (for an effective understanding) might be a holistic thinker, because in many cases, geological phenomena are not caused by a single event, but usually as a result of several different geological causes. A holistic thinker is able to use existing knowledge to determine any possible link between other areas of knowledge, or, if there is no link, then they should wonder why not.

Students in the category of linear thinkers do not seem to lack the knowledge to refer to single geological phenomena, but lack the ability or intent to re-organize their existing knowledge.

(B) Synthetic but Non-Geological Sense (refer to appendix 9 – appendix 12)

This group of students do have the ability to re-organize what they have learned and formulate their own opinion but, they do not necessarily apply geological sense to make a final judgement as to whether volcanic events and earthquakes are linked. They usually integrate many different kinds of Science knowledge and then synthesize their own understanding. For example, some students believe that there must be some link between earthquakes and volcanic events. They believe that these two movements are both related to a change in energy form, and therefore, there must be a link somewhere. This classification contains Type (a) (Understanding scientific concepts and with correct interpretation) and Type (b) (Having some scientific concepts but with incorrect interpretation). The above students' theory is not wrong. It can be a rough understanding, and although they did not apply any knowledge from Earth Science, their logic still matches some parts of knowledge from Earth Science. Perhaps, this part of knowledge can be called "common scientific knowledge".

Another example is that some students believe that, when either of the geological events occurs, it could touch off the other. The main reason given is that both volcanic movements and earthquakes occur in the ground, and ground systems might be connected; hence, the two events might be positively related. Other students hold a very different opinion. These students believe that there is no link between earthquakes and volcanic events, because they think that earthquakes are vibration, and volcanic events are eruptions. Although they are all Earth movements, they are in a different mode, so there is no possible link. Besides, they have never seen a volcanic event touch off an earthquake or vise versa. These students have already thought about the possible relation between different movements. They are not linear thinkers, and although their thinking may not arrive at the truth, basically they exhibit clear logic. At the moment, they see things in microcosmic view or they haven't received enough knowledge yet, but they are reticulate thinkers, which means that they can handle and use the knowledge they have already acquired, whether the concepts are correct or incorrect. Their learning is more effective than that of linear thinkers. They can use existing knowledge as a "gangplank" to connect the knowledge they have already learned and matters they are not really sure about. The correct or wrong answer is not really important here; the most important point is how students develop their own thinking, and how they apply limited theories to explain further relevant concepts. Students who belong to this category seem to try to build up an explanatory theoretical model by applying synthetic knowledge. Their performance seems remarkable, though the results are not always correct.

(C) Geological Sense (refer to Appendices 9 – 12)

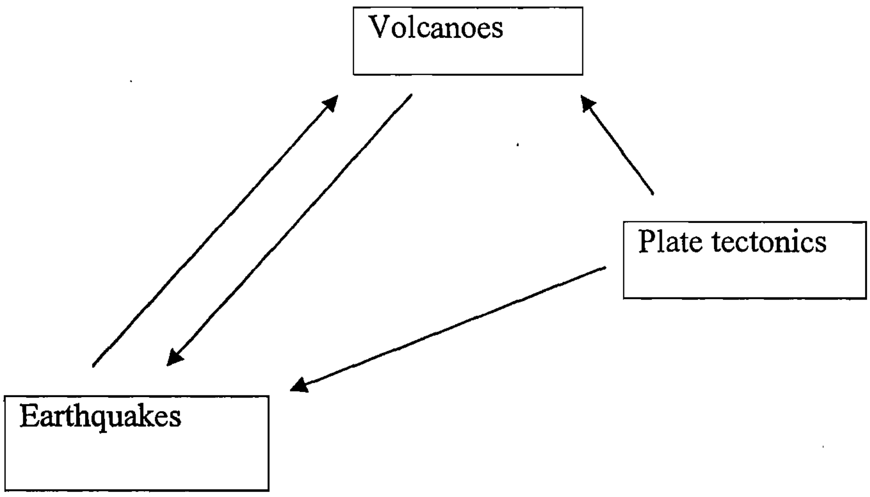
A number of students do seem to make very clear geological sense. They show this in their belief that volcanic events and earthquakes are related (Senior level 24%, Junior level 24%, Primary Year 6 26%, Primary Year 3 15%). Some students believe that although volcanic events may touch off earthquakes, it does not mean that the strength of an earthquake is powerful enough for people to feel it, and this might be the reason why people are not really sure whether these two geological events are linked. Students in this classification are of Type (a)+(e) (Understanding scientific concepts and with correct interpretation plus geological concepts).

Again, most students have not experienced any volcanic events in person. That volcanic events and earthquakes affect each other is their own inference. Several students indicated that any kind of volcanic event must involve heat convection, and heat convection relates to plate tectonics, and earthquakes are the result of plate tectonics; consequently, earthquakes and volcanic events are related.

In fact, in the case of the above idea, students not only have the ability to make an inference, but also have a clear understanding of the Earth's internal structure. These students indeed are holistic thinkers, but also "dual-convection" thinkers, because the "key bridge" for them in the above example is plate tectonics. Students seem to start their inference from both sides, with volcanic events as one starting point and earthquakes as another, and then consider any possible relation between the two geological event in a "dual-convection" model (shown below). Finally the result intersects in the conception of plate tectonics.

Students who are able to make this inference have not only understood volcanic events and earthquakes well, but also understand other geological concepts well too, because when they try to confirm whether the two events are related or not, they have to go through many geological concepts and revise the ideas properly. Each geological concept could be a conceptual connector, and if they do not have the basic understanding of any concept properly, the inference cannot be made. However, students also understand that, although volcanic events and earthquakes are related in some ways, it does not mean that they always touch each other off every time. Students who can make inferences seem not to put any one geological concept as a central idea and then link other relevant concepts to this central idea. Contrarily, what they do is more like treating each geological idea equally, trying to fit every possible piece of information from each concept together in a new conceptual arrangement. It is like a jigsaw puzzle (in this case, the picture is the relationship between volcanic events and earthquakes). If the puzzle can be solved by using information from a variety of existing geological concepts, then the answer for the student is positive, and the inference is successful.

Schematic Diagram of the Dual Convection Model



4.6 Evaluation of the two data collection method-interview and drawings

Comparing the drawings with the interview data provides a range of insights. To illustrate, suppose that ten students were interviewed and made drawings. It is possible that the drawings fit exactly what was explained in the interviews. But there are other possibilities, as follows:

(1) The students explain one way and draw something quite similar.

(2) The students explain one way but draw differently.

To illustrate another way, suppose that, in a group of ten students, one characteristic of a volcano shows up 7 times in the interviews and 3 times in drawings. It could be that all the students who made the drawings are included in the set of 7 from the interviews. It is also possible that the 3 from the drawings are different students altogether. Finally, one or two could belong to the set of 7, but the other(s) not.

During the data collection phase, each student's interview results and drawing were stapled together and a count was made to see to what extent the drawing matched the statement(s). Then, I picked 15 students from each study level as samples to track their interview statements and drawings. Roughly speaking, I found that only about half the students (50%) drew according to their interview statement, but there was some variation according to the earthquake/volcano characteristic in question. Some reasons will be suggested below.

Looking specifically at the raw data and Table 4.31-2 (Earthquake drawings) together with Table 4.18 (interview results), there is a clear match in some categories between what students said and what they drew. Around 70% of students talked about shaking/waving and illustrated it in their drawings. For example, one nine-year old student with little knowledge or experience of earthquakes expressed fear of "shaking" in the interview and drew a picture of an item of furniture tilting and shaking (indicated by short lines-<<...>>). A twelve-year old student highlighted shaking in the interview. The drawing included several details: Parallel wavy lines indicating earth movement, casualties and people in flight, and the usual symbolism of shaking and cracking buildings. A similar picture is drawn by a fifteen-year old, who referred to ground movement and shaking in the interview and drew a five-storey erect building with wavy lines on the outside walls. A seventeen-year old spoke of shaking (earth) surface and shaking room. His picture showed two rectangles (plates) displaced, with long wavy lines between them and the "shaky" symbols down each side. This is among the high categories of correspondence. At the other end of the scale, a small number of students were able to illustrates earthquake casualties, but not one had been able to speak about it. Appendix 33 (Primary Year 6 student drawing) shows a multi-storey building affected by earthquake (breaking up). A stick figure drawing shows a person at a top floor window. A second figure is falling head first to the ground. Appendix 34 (Primary Year 6 student drawing) has a stick figure with crosses (X X) for eyes, on what might be a representation of a hospital trolley, with a smiling guardian angel standing behind. Although the majority of drawings do not contain stick figures, those that do usually show figures moving away from a scene of catastrophe, or sheltering, with very few drawings of fatalities and, as I said, with no mention of them in the interviews. There may be a cultural reason for this. The background culture is Taoism, in which speaking about death or observation of it is almost taboo.

Another earthquake category with low correspondence between oral and visual representation is Earth's internal structure (with only about 30% matches). Students may have some ideas about movement under the earth's surface and can visualise it and illustrate it in more or less complex ways. For example, the drawing in Appendix 70 shows a shaky building with a thin symbolic, wavy line leading to it. This shows an idea, but a lack of deeper knowledge or understanding of Earth's internal structure. The results indicate that, while children have some idea about earthquakes, they lack the knowledge, the understanding or the linguistic ability to express it adequately in words.

Turning to volcanoes, the results show a similar pattern. Many features of volcanoes are easily visible (even if not seen at first hand), such as almost all the items in Table 4.3 (lava flow, smoke and so on). A high match between interviews and drawings was found for lava flow (around 80%).Generally, the young Primary school students were not very informative about volcanoes, but frequently referred to "lava". More students were able to draw the shape of the "volcanic mountain" than to describe it (Tables 4.15-2 and 4.2, respectively), although "Mountain" was in the top two categories in the interview. Similarly, many more students thought about drawing the "hole" than about describing it. One nine-year old drew a tall mountain with a jagged crater, gases and lava flow, but only "lava" and "heat" were noted in the interview. A twelve-year old spoke of gas, lava and heat, but his picture only showed a house being (symbolically) engulfed. A thirteen-year old spoke of lava and fire and drew exactly that on a tall mountain. One illustration of casualties and several of damage appeared in the drawings, but not in the interviews. I think it is perhaps easier for a young student to add a detail to a drawing and harder to link up ideas in words. In all the drawings of volcanoes from both Junior and Senior high schools, stick figures occur only three times. One fifteen-year old referred to ash, lava and shaking during a volcanic event. His drawing was of a distant volcano, a car in somewhat (symbolic) rapid downhill motion, and two figures in the foreground running. There is no apparent casualty. An eighteen-year old refers to lava, heat and a lack of "time to run". His picture reflects this. The background is a tall mountain with a large crater, a huge plume, lava and falling rocks. In the foreground is a figure safe from danger. In the middle ground is one fairly safe and another much too close to the lava flow. The most graphic human danger is depicted by another fifteen-year old, who referred only to lava flow in the interview question about volcanoes. The interesting aspect in his case is that he was marked by hearing of loss of life in earthquakes on the television news. His earthquake picture shows two connected wavy earth lines, around which are three figures, perhaps prostrate, limbs spread, a "dazed" cartoon symbol, wavy lines for eyes shut and tongues hanging out. Interestingly, the volcano drawing shows a simplistic explosive mountain and four figures identical to the ones in the earthquake in the foreground.

The trend continues as regards volcanic internal structure. More than twice as many students could illustrate some ideas of it than could express understanding in words. Therefore, the results for earthquakes and volcanoes support each other, even though the two phenomena are different in nature.

It seems that students have more ideas about the characteristics of volcanic events rather than those of earthquakes (average characteristics appearing in drawings of earthquakes is 2.19, average characteristics in drawings of volcanoes is 3.32), though most students had never personally experienced any volcanic event; conversely, most students had experienced several earthquake events in person. This might suggest that the geological characteristics (earthquake events and volcanic events) in students' drawings are not necessarily related to students' experiences. It seems that they are more related to the nature of geological events, and information resources that can attract students' attention, a key influence. For example, as I mentioned, students do receive some volcanic information from Hollywood films, and students do pay attention to and show interest in these films;

therefore, although students have never experienced volcanic events in person, they do have a chance to receive frequently (but not completely) volcanic information from the media. On the other hand, although most students have experienced some earthquakes and also have proper training to protect themselves from potential earthquake hazards, the most common characteristic of an earthquake is shaking/waving, which can be sensed, but not so obviously seen by the students. The nature of the geological characteristics of earthquakes might reduce students' abilities to draw them. Hence, the obvious difference between drawing a volcano and an earthquake is about drawing direct visible characteristics and drawing indirect invisible characteristics: shaking/waving can be seen directly but its causes cannot; therefore, students draw shaking lamps, shaking cabinets or a curvy line to ***represent*** the earth shaking. Moreover, "people's reactions", "casualties", and "damage" are all indirect expressions of earthquakes, with less drawing of internal Earth structures.

Conversely, students are able to draw both the direct and indirect characteristics of volcanoes, for example: "lava", "mountain in steep or smooth shape", "Earth's/volcanic internal structure", "a hole in the top of the mountain", "smoke" and "fire". These are all direct characteristics of volcanoes. Students drew the above characteristics as parts of volcanic events, because these characteristics can be seen while the volcanic events are happening. Other indirect characteristics, such as "casualties", "people's reactions", and "damage", which are caused by volcanic events, are not necessarily a part of volcanoes.

Again, these sorts of indirect characteristics are just to ***represent*** volcanic events.
It can be found from students' drawings and feedback that, although students produce on average more characteristics in drawing a volcano than an earthquake, it does not mean that students have more knowledge or experience about volcanoes. In fact, from the feedback in the interview, students seemed more familiar with earthquake events; therefore, it looks like the ***nature*** of geological events and information resources attract students' attention and play a key role in their ability to draw them.

I have analysed the research data and discussed the findings in this chapter. In the following chapter, I discuss the conclusions, limitations and implications of the research.

Chapter 5 Conclusions, Limitations and Implications

5.1 Introduction

In this final chapter, I discuss the limitations and implications of this research and put forward some conclusions. This chapter comprises the following sections: 5.2 The students' original ideas concerning earthquakes & volcanic events and their learning status, 5.3 Examining the curriculum design in Earth Science and General Science, 5.4 Examining students' first training/instruction when facing earthquakes and volcanic events, 5.5 Summary and Conclusions. The latter draws together the conclusions from section 5.2 to 5.4 to answer the research questions, which I present here again briefly, for the readers' convenience:

Research Question 1

How much knowledge do students have about earthquakes/volcanoes and related events, and what is the status of their understanding of the phenomena?

Conclusions regarding this question are discussed primarily in section 5.2.

Research Question 2

What are students' ideas concerning the relationship between earthquake and volcanic events?

The conclusions are put forward in section 5.2 and part of 5.3.

Research Question 3

Have the students' own experiences of earthquakes and volcanic events prepared them to know what to do when they happen?

This discussion is in the conclusion of section 5.3 and in 5.4.

Research Question 4

Can the findings be used in curriculum development in Taiwan?

This is discussed in section 5.3.

Finally, I will try to suggest what further research could be done in this area.

5.2 The students' own ideas concerning earthquakes & volcanic events and their learning status

Students' own ideas about earthquakes and volcanic events vary. They do not seem to develop in even, gradual steps according to study level. On the contrary, their development appears quite uneven. Some Primary students and Secondary students have equal understanding in a particular area. This is easy to see from their oral responses and annotated drawings (specific examples are given below.). From my data analysis, the evidence suggests that students' conceptual development comes from many different sources and influences, as indeed one might expect. No single knowledge resource is able to provide a full learning source for any one student at any time. Moreover, the same student might be attracted to different knowledge sources at different learning stages. For example, some students might have first contact knowledge from their parents (some of the students' parents incidentally are school teachers/specialists), and as students are able to use an internet information service, then they have even more knowledge resources available to them. Another example is that when students go to school at Primary level, even though they do not follow full courses in Earth Science, they do at least have two sources of information available: one from the General Science course and one from the school library. Another hugely important source of knowledge is the media. Many students have seen the Hollywood film "Volcano". According to the students' responses, almost none of the students had ever personally experienced a volcanic eruption in person. However, after watching the film "Volcano", many students fully recognized the nature of volcanic phenomena as shown in the film. It is hard to say whether the outcome is good or bad in one word. On the one hand, the film realistically simulates events, is quite plausible from a geologist's point of view, and gives students a relatively strong and vivid understanding of what might happen before, during and after a volcanic event. On the other hand, the simulated events are not necessarily true for every case, such as water boiling in the lake, pond and pool. Students might regard all the simulated volcanic phenomena as inevitable.

In the light of the above, it seems that, even at the same study level, students may have differing understanding of earthquakes and volcanic events. A volcanic eruption might contain any or all of the following aspects: Plate Tectonics, Heat Convection, Volcanic ash, Lava, Evacuation Plan, First Aid preparation, etc, and students in the same class may have varying degrees of understanding of these different aspects.

Whether from early Primary level or Senior level, no one student necessarily fully understands all aspects of volcanic events (or of earthquakes). Students might understand some aspects better than others, and appear to advance their understanding slowly but unevenly. The manner of learning seems to be like patchwork making, where any single event, for example an earthquake or a volcanic eruption, involves several aspects. The order in which the work is achieved is not necessarily important. It just so happens that the students may tend to focus first on lava flow at the centre of their work, because lava flow is an obvious symbol of volcanic events. Nevertheless, very few younger students spend a lot of time or pay detailed attention to the study of lava. Furthermore, no one seemed to be aware that underground melting rock is called magma instead of lava, and no one could tell me about the alkalinity or acidity of lava. This was unsurprising and I did not expect otherwise. Similar confusions were reported in Larson and Birkland's (1982) research, even amongst older students, as well as by Oversby (1996). Students might understand lava as a sort of hot and powerful material, and this is about the end of their focus. After that, they may transfer their attention to another relevant key piece of knowledge, volcanic ash for example. Here again, they may not spend a lot of energy in studying volcanic ash. It seems as if when the study of volcanic ash is too difficult to excite further interest, students may transfer their attention to another key area of knowledge of volcanic events, and so on, to come round full circle, sometimes repeatedly, adding greater detail each time. If one area is not complete (key knowledge/concept) they may rotate their focus at varying speeds, like turning the patchwork around, adding pieces and adding detail. This model of learning could also be labelled "Rotational Learning".

An illustration is useful at this point, and there is no better way of illustration than the drawings of the students themselves. A large number of students in Primary Year 3 drew the truncated conical shape typical of volcanoes (for example the drawing in Appendix 28) with representations of lava on the upper slopes. This kind of drawing persisted throughout the study levels, but, at the same time, new representations appeared at each level. For example, in Appendix 39 (Primary Year 6), a similar drawing appeared, but the destructive potential portrayed was much stronger: the lava starts to engulf forests and force people to flee. An addition in Junior High School (Appendices 54-55) is arrows indicating the upward movement of magma, while in Senior High School the Earth's crust is included

(Appendix 74) and a deep magma chamber is illustrated (Appendix 80). Thus, new kinds of knowledge complete the picture surrounding the nucleus and expanding outwards. When students begin their patchwork picture, their initial understanding of every item (volcanic ash, lava flow, etc) might be incoherent or incomplete, and gaps need to be filled. Because of such incoherence, it might not seem obvious that Secondary students have more understanding of a particular key knowledge area than Primary students.

All this seems to point to a generally "constructivist" account of students' conceptual development, but one which needs to take adequate account of the role of instruction certainly, and of classroom instruction and practice, as well as of other sources. As with many other fields of knowledge that figure prominently in schooling and in science education, the concepts that are fundamental are revised and even reformulated many times over, whether on discrete occasions or as a continual movement, as the students' understanding develops. This approach to the analysis of students' work may help to develop a new model of learning (one that may also be applicable to other areas). The children's drawings, for example, give a strong indication of the scope of their understanding. This might then be compared with the aims of the curricula. If evidence is gained of a discrepancy between what students have known and are expected to know, it should be possible for teachers, curriculum or textbook designers to revise their course input or reinforce various areas of learning, the focus being very much on the learner. The Table 5.1 displays the discrepancies about the concepts which pupils have already known and expected to know (based on the evidence from the interviews, annotated drawings and textbooks). The discrepant percentage of pupils' conceptual understanding in Table 5.1 are examined through each table and figure in chapter 4; I sum up all volcanic and earthquake concepts, then compare with the concepts which pupils are expected to know in the textbooks, and in the end, I adopt the closest integral percentage as a general result.
The discrepant data shown in Table 5.1 suggests that primary pupils only handle 50% of relevant concepts which they were expected to learn. However, their personal geological experiences seemed to be an extra source of learning, because obviously they were able to mention more earthquake concepts rather than volcanic concepts.
Pupils in Junior high school have more understanding in both relevant concepts, but they were still familiar with earthquake concepts rather then volcanic concepts. It seems that pupils' conceptual development below Junior level might be influenced in certain level by their own geological experiences, and the even development of both concepts only

appeared in Senior high school level. At all levels, the pupils do not show mastery of all concepts, although mastery does increase with age. The detail already discussed of pupils' understanding of key concepts at different ages may help curriculum developers consider the best placing of key concepts in the curriculum.

Table 5.1 The discrepancies between what pupils have known and are expected to learn/know

School grade	Earthquake and relevant concepts expected to learn	Volcanic and relevant concepts expected to learn	The discrepancies between what pupils have known and are expected to learn/know
Senior level	Circum-Pacific Earthquakes/Seismic zone, Seismic waves, Internal Structure, Orogenesis, Plate tectonics, Faults, Crustal movement,	Volcanism, Circum-Pacific Volcanic zone, Metamorphism, Fumarole, Igneous effects, Internal Structure, Seismic surveys, Oceanic volcanoes, Magma, Intrusive movement,	Most pupils almost have equal understanding between earthquake and volcanic events, they can understand more than 80% of concepts which they are expected to know in both earthquakes and volcanic events.
Junior level	Stratum history Fossils The evolution and formation of the Earth, Plate tectonics, Mountain movement, The formation of mountains ,	Natural resources, The evolution and formation of the Earth, Plate tectonics, Mountain movement, The formation of mountains,	Most pupils have better understanding about earthquake events, pupils are able to handle 70% earthquake concepts they are expected to know, but they can only talk about no more than 60% of volcanic concepts which they are expected to know.
Primary level	Different topographies, Geo-disasters in general, Land-formation, The movement of geological layer, Lithosphere,	Geo-disasters in general, Land-formation, Rocks, Minerals, Lithosphere, Resources,	Most pupils do not have good understanding in volcanic concepts, they only handle no more than 50% of relevant concepts. They have better understanding of earthquake events, but they are only able to handle no more than 60% of relevant concepts.

When working on a patchwork picture, it is necessary sometimes to stand back and evaluate the whole effect. This is equivalent to an end of term/year/school assessment; it can be used to focus students on gaps in their existing knowledge.

This development involves logical and linguistic elements importantly, as well as the learning of facts and the ability to "read" visual information in diagrams, photos and icons, for example. Whether involving relatively discrete "intelligences" or otherwise, the developmental process here is complex and far from uniform between individuals or for the same individual at different times. The key point here is that a model of learning may have evolved (the patchwork or rotational model). This will be discussed further below, along with another model, the Hammering Home model.

5.3 Examining the curriculum design in Earth Science and General Science

As a result of the preparation work and data analysis for this study, I found that the Taiwanese curriculum design in Earth Science and General Science could be described as presenting a "Hammering Home" learning model. What I want to indicate by the "Hammering Home" label is that the Earth Science and General Science curriculum is designed to ensure Primary students and Secondary students ***fully*** understand each single event at each stage. For example, at early Primary level students are expected to fully understand particular sorts of events (earthquakes or volcanic events). When students have reached a minimum academic standard, they move to the next level (higher standard). But, as I mentioned in the earlier section, any single event (an earthquake for example) might contain several areas of key knowledge. The design of the General Science and Earth Science curricula however is to divide those key knowledge areas into several components at each learning stage standard. Students are asked to reach at least the minimum standard at each learning stage.

They receive a snapshot view of events (such as earthquakes), a picture comprising several components of knowledge, for example, seismic waves, fault movements, tsunami, plate tectonics, etc. Unlike the patchwork, which can be returned to in the future, this picture is

filed away and will not be edited in the future. Instead, a new picture is started in the next stage. Each stage can be seen as a "Hammering Home" of key concepts.
The problem with this sort of "Hammering Home" is less obvious at the lower Primary level, because the key knowledge in the lower Primary level is intended as not too difficult to understand; students might not lose their focus on it so easily. It is not too difficult to snap any small section or sub-section and drive home the picture, so to speak. However, from Junior level upward, Earth Science as an Applied Science requires more specific key knowledge to comprehend any single event (earthquakes and volcanic events), and students develop varying degrees of interest in different areas of the subject. When students lose their focus on a particular area of knowledge, it becomes almost impossible for them to maintain their view of the larger picture. Thus, it becomes difficult to further their understanding in an effective way. It seems that the model of learning behind the curriculum design expects students to have an even understanding of each key area of knowledge and an equal and undifferentiated focus on all aspects, which seems to me unrealistic, based on the evidence from the interviews.

In fact, what I have seen from students' responses in this research is that most of them do not maintain an even level of interest in each area of knowledge. I think that this is quite natural. Everybody has varying degrees of focus on different aspects of knowledge. It seems more realistic and more helpful to view learning as an ongoing process. For example, students are first introduced to the difference between energy and energy sources in Primary Year 6, but less than 50% of the students were able to describe it. According to the "Hammering Home" model, more than 50% of students should be able to do so. Students did not seem very focused on energy and energy sources at this level. However, students rotate their attentions to other relevant areas of knowledge, leaving this particular key element of knowledge relatively under-developed. However, by rotating their focus towards new knowledge, their understanding progresses in the patchwork of Rotational Learning.

The failure of students to identify the difference between energy and energy resources could also be seen as a weakness in the Rotational Progress learning model, as gaps in knowledge are unavoidable in the process. From students' feedback, most students seemed to have spontaneously adopted the model of Rotational Learning. Its advantage is that students can shift their focus to areas of knowledge and make progress in their understanding of the single larger event. It is actually a kind of self-initiated learning, so students should have less difficulty in the process of learning. The main apparent disadvantage is that, although students might make good progress in their understanding of the larger event or general phenomenon, Rotational Learning can result in many knowledge gaps. Students might understand the overall frame of a particular single event, but they lack detailed understanding or precise knowledge.

The "Hammering Home" model sets students a basic standard of concepts to be learned. The advantage is completeness at each step, coherence and a systematic approach. The disadvantage is that it presents learning obstacles for students, because the subject matter may appear un-related to students' daily lives, overly theoretical or academic and dry, and outside students' interests.
What happens, as I have mentioned, is that students tend to focus on what they are interested in and to give less attention to the areas of knowledge which don't attract them very much. Generally speaking, the students' effective learning approach has already departed from the original curriculum design in Earth Science and General Science. Interview evidence suggests that most students have already adopted the Rotational Progress learning model spontaneously instead of the model the curriculum dictates. There is no judgment of right or wrong, good or bad implied, regarding either learning model. I will bring up further suggestions and discussions however in the final section.

The review of the literature in Chapter 2 relevant to my own research raises a numbers of points for discussion. The literature I reviewed documents and discusses research carried out over the last four decades into science education in many countries of the world, including Britain, America and some Asian countries. Not all of the research reviewed was specifically in the area of Earth Science, and none of it was focused perhaps as tightly as my own research, which looks very specifically at children's concept development in their learning of a relatively specialized area of Earth Science. Specific conceptual routes and pathways involved in the process of knowledge acquisition and concept learning in earth science are poorly known, but seem to involve a series of possibly identifiable steps. My review of the literature suggests that there is evidence for a progression from descriptive to explanatory, with often visual and stereotypical images and terms in the early years of learning, giving way, in Years 6-7, to modes of understanding, of conceiving and talking about geo-phenomena that take account of causal factors and inferences from underlying causes. This seems to be borne out too in my own research, which I present in Chapters 3 and 4. There appears to be little evidence in the literature, however, for stereotypically "mythical" explanations, even amongst younger students. I suspect that this might be due to the fact that the research was conducted in countries where mythical, poetical or religious modes of explanation are culturally on the wane, where scientific or quasi-scientific discourse has actually largely displaced the more archaic discourse of myth and metaphor. Indeed, in the literature, it was American children in Ross & Shuell's (1993) study that showed most evidence of such thinking.

There seem to be remarkably similar confusions in thinking, however, and remarkably similar misconceptions and "blind-spots" across the board in some areas. The research of White (1988), Larson and Birkland (1982) and of Oversby (1996), all note similar misconceptions to many I encountered amongst Taiwanese students, specifically regarding the earth's internal structure, lava/magma and the processes of rock formation. In Oversby's research, such misconceptions were cited even in the case of graduates and trainee teachers!
Despite the difference in focus and despite the difference in the cultural background in education, the reviewed literature does indeed suggest a number of points related to my own. Two points that seem most obviously relevant to my own research are:
(a) The prevalence of (or perhaps even, necessity for) intuitive/ "alternative" models of learning for younger children. The findings in the reviewed literature seemed to accord with my own, with evidence found for a development from, say, "mythical" to more "scientific" description and explanation. The researches of Butterworth et al (1997) and Ross & Shuell (1993) are the most pertinent.
(b) The perceived progress from a "superficial" focus on appearances and descriptions of results of events to a "deeper" understanding of Earth structure and the causes of events is highlighted by Good (1963), Wiegand (1991), Happs (1982 b), Russell et al (1993) and Ross & Shuell (1993).
So, these findings from other research add some support for a learning model which encourages a deeper re-visiting of concepts over time, i.e. the Rotational Progress learning model.

5.4 Examining students' training/instructions and immediate reactions when facing earthquakes and volcanic events

Put briefly, students do seem to have adequate knowledge to protect themselves in the case of earthquakes, but have less adequate though still some knowledge and logic to minimize risk in the case of volcanic events. The research was undertaken in Taiwan, however, where earthquakes are a constant and real risk, but volcanic eruption poses an almost negligible threat, so that minor inadequacy in terms of preparedness is understandable and probably justifiable. What I could not observe was students' psychological state or reactions on the spot in the event of an earthquake (or volcanic event). It is difficult to foresee whether students will react properly without panic and follow the instructions as they have been trained. What I could see was that students were well trained and had the knowledge to react appropriately to earthquakes. Ross and Shuell's (1993) research touched on earthquake preparedness amongst Primary school children in the USA, which seemed to suggest that American children, including those living in the main fault area of California, were not best prepared at the time their research was undertaken. Possibly the Primary level students in Taiwan (2004-2005) were better prepared, though whether this was solely a result of instruction received at school was questionable.

Most students seem to have better knowledge regarding what to do before and during earthquakes and volcanic events rather than what to do afterwards. This shows that although a good training programme may help students to survive earthquakes and volcanic events, relatively few know how to provide for others and help themselves afterwards (for example, what they can do before a rescue team arrives, how to be involved with rebuilding a disaster area and recovering their own mental/emotional stability). I think that the educational authorities should enhance these aspects of training for students inside the curriculum.

5.5 The Combinative Learning Model

I have discussed the advantages and disadvantages of the Rotational Learning model and the "Hammering Home" model in the previous sections. Here I might suggest that curriculum design should encompass both models, and apply them at different learning stages. The Rotational Learning and Hammering Home Learning models can be merged as a Combinative Learning Model (CLM), which simply means combining the models, as explained below.

I suggest that at early Primary level, the curriculum should continue with the "Hammering Home" learning model. This is because the general scientific knowledge is relatively simple, though the concepts underpinning it are essential and fundamental. Students need a solid and complete understanding of them as a foundation for Applied Science and Earth Science at Secondary level.

Students at Secondary level should already have a solid and complete foundation in relevant scientific concepts. When they are first introduced to Earth Science (an Applied Science that includes importantly the study of earthquakes and volcanic events) the curriculum design might shift from the "Hammering Home" model to the Rotational learning model. It should allow students to change focus and in a more flexible manner integrate their general understanding of earthquakes and volcanic events without losing interest in particular areas. Some degree of Hammering Home might be retained, if students do not seem to be progressing enough in the rotational learning model. However, it should be acknowledged that gaps may occur.
To offset these knowledge gaps, I suggest that there should be no hurry at the Secondary learning level. Through Rotational Learning, students may acquire the general framework of scientific knowledge about earthquakes and volcanoes. The more detailed and difficult areas can be dealt with in higher education for those specializing in Earth Science.

Schematic Diagram of the Combinative Learning Model

Hammering Home Learning Model

1. "Hammering Home" is designed to ensure students fully understand each single event at each stage.
2. Any single event (an earthquake for example) might contain several areas of key knowledge.
3. Students are asked to reach at least the minimum standard at each learning stage.

Rotational Learning Model

1. Students rotate their focus to other relevant areas of knowledge, leaving some elements of knowledge to be completed later.
2. By rotating their focus towards new knowledge, their understanding progresses towards the full picture in patchwork style.

Combinative Learning Model

1. Students learn simple but essential concepts that should be understood at an early stage.
2. More complexity develops at a higher level.
3. Complex relations are established between concepts in Junior High School.
4. The concepts are introduced and revisited in the rotational approach.

Applying the Combinative Learning Model

It seems to me a combination of Rotational Learning and "Hammering Home" is very much in the spirit of the Constructivism discussed in Chapter 2. There are two parts to the Combinative Learning Model (CLM) applied to Earth Science learning that conform to Constructivism.

Part (A): At Secondary level, students already have a basis in scientific concepts, and general knowledge of earthquakes and volcanic events is based on applying those foundational scientific concepts that students have already acquired at Primary level.

Part (B): After Secondary education, some students may go on to study Earth Science in higher education. Then, the specific and detailed theories regarding earthquakes and volcanic events can be constructed on the basis of the geological knowledge established at Secondary level.

Secondary students (Part A) should have the ability to understand the basic movements of the Earth and understand what might happen in a real life earthquake or volcanic eruption. Based on the above abilities, students are also able to make an emergency plan to deal with the hazards and know what to do next. The point here is not to expect students to have specific or detailed knowledge of earthquakes and volcanic events, but students should have general and practical knowledge, which they might need to use one day. The truth is that not every student will study Earth Science in higher education.
Students who reach higher education (Part B) are expected naturally to have more precise understanding of earthquakes and volcanic events, and it is they who may be expected to be the professionals in the Earth Science field eventually.

I believe that the combinative learning model can help most students to reach Part (A), and for those who choose it, Part (B). The Combinative Learning Model (CLM) I suggest draws support from Constructivism, whereby knowledge/conceptual gaps are filled in.

5.6 Strengths and Limitations of the Study

The strengths and limitations of the research are summarized below:

Table 5.2 Strengths and limitations of the study

Strengths	**Limitations**
The interviews produced a wealth of detailed data.	This study only captured students' understanding at one instant in time.
Insights were gained into the progression of students' understanding.	The research model could be better tested and re-evaluated in different subjects and longer time-scales.
Students' drawings provided complementary data to the interview.	The results do not reflect students' learning efficiency from the class teaching.
Verbalisation and visualization revealed differing features.	The results do not reflect students' actual reactions when an earthquake or volcanic events occurs.
The combined results suggested a model of learning.	This study might only represent particular samples.
Practical and theoretical recommendations were enabled.	Further longitudinal tests could be carried out through interview and annotated drawings.

There are generally 6 strengths and 6 limitations showed above, I would like to introduce them starting with the strengths. First of all, the interview produced a wealth of detailed data, this is one of the major benefits from carrying out interview (Cohen, 2000), according to the results, one-to-one interview did collect a lot of data about pupils' ideas in volcanic and earthquake events, and pupils' drawings also help me to confirm or compare with interview results.

Many insights were gained into the progression of pupils' understanding, these parts of result were mainly from the interview, because during the interview, I did add some additional questions to confirm pupils' understanding, and these confirmations become important supports to understand the progression of students' understanding.

Interview and annotated drawings have their own features in data collection, one is focus on verbalization and the other one focus on visualization, and because of the different features, I am able to re-examine pupils' concepts in different way. Of course, there are some limitations in this study and leave some potential researches worthy of further study. I chose a particular framework for analyzing the interview data and have shown how the evidence, presented in comparative tables, supports the findings. There are clearly other possible ways of analyzing and interpreting the interview data. However, I have attempted to be as rigorous and coherent as possible in the analysis in order to have confidence in the research findings. Some more longitudinal tests could be carried out through interview and annotated drawings in order to pursue the development of understanding in a truly longitudinal, rather than cross-age way. This study only captured students' understanding at one instant time, in other words, it is a sort of "snap shot" of pupils' understanding. If I interview the same pupils and ask them to do annotated drawings again, the results might be slightly different. Therefore, this research result might only represent a general status of pupils' understanding in such circumstance, and the more that longitudinal interview and annotated drawings could be carried out, the more accuracy of pupils' conceptual understanding could be seen.

Also the research model could be tested and re-evaluated in different subjects and longer time-scales, depending on the research focus, either interview or annotated drawings could be adopted as a main method.

Finally, neither interview nor annotated drawings can provide students' learning efficiency from the class teaching, and this is the natural limitation of these two methods (Cohen, 2000), furthermore, this study cannot reflect students' actual reactions when an earthquake or volcanic event occurs, and this is also the natural limitation of these two methods (Cohen, 2000).

Research in most fields is limited by the constraints of time and resources. The present study makes a useful contribution in two ways. First of all it supports research conducted in other parts of the world. For example, Chula 1998 in the United States describes how drawings can be used to displaying understanding of learner's knowledge and Oversby (1996) saw confusion in children's ideas about what constitutes a fossil. The present study focused on Taiwan, and on a narrow area of children's learning and knowledge.

Interviews and drawings worked together well in conceptual comparison, particularly in comparing the characteristics of earthquakes and volcanic events. It is important to know to what extent school pupils can verbalize their understanding of geological events and to understand their limitations in terms of verbalization. Such understanding of children's minds is key to teachers and curriculum designers if they are to prepare suitable lessons and develop effective class activities. The idea of collecting drawings proved useful, as the conjunction of verbal and visual data provides a much broader understanding of the students' level and range of knowledge. Some aspects of volcanoes and earthquakes were difficult to verbalize, but could be indicated symbolically in drawing. Verbalization is of course important in the learning environment, either in classroom discussion or in written coursework. Teachers could therefore use the students' own drawings as the basis for further discussion and to develop knowledge. Ultimately, successful verbalization can lead to more awareness among the general public.

However, there were differences between the detail of responses to interview questions and that shown in the annotated drawings. It is difficult to determine which method, verbal explanation or drawing, provides the most reliable source for understanding pupils' views. Although there were differences in individual cases between the understanding shown through explaining and through drawings, the differences are not so large as to undermine the general trends shown collectively from the two instruments and it has been important to look at both data sources together. Greater reliability might have been achieved by respondent validation-i.e. showing the interpretation of interview and drawing data to individual respondents to see if they agreed with the interpretation. However this was not possible, logistically. It could be valuable in future studies to look more closely at the intentions of the two different methods, working together and their expected congruence in any interpretation, as only by combining the outcomes from both methods can a rich picture of students' understanding be seen.

Individually each method, explaining or drawing, has its limitations-some pupils may have difficulty expressing their understanding verbally or visually.

The data collection proved adequate for the purposes of the thesis. In terms of the drawings, the problem of children saying "I can't draw" (Chula,1998) was successfully avoided by having children focus on the practicality of the task, rather than be concerned about the artistic merit of their work. In that sense, the students were obliged to come up with something, however simple, to illustrate their knowledge.

The methods of data collection could be applied to other areas of learning in Taiwan, in general education, in schooling for the exceptionally gifted or for those with learning difficulties, and across a wide range of subject areas, such as geography and history.

A most important extension to the current study would be a longitudinal one, in which different teaching and learning methods could be compared over a period of years, using control groups and specially selected evaluation methods. Although the sample population was again adequate for the present study, there is no limit to the sample size that could be adopted in future studies.

In terms of the data analysis, the discovery of themes in the content of interviews and drawings (and the differences between the data gathered in each) proved valuable, interesting and fruitful. The interpretation of the data has been mine. Other researchers might have used different frameworks for analysis or found slightly different patterns in the data. However, the presentation of data and analysis has been rigorous in order to show how major themes were identified. The findings show what students can and cannot verbalize, and throw light on how they visualize events and the extent of gaps in their knowledge. In that sense, whatever the limitations of the data collection methods and analysis, the contributions and benefits of the study are substantial. The findings can feed directly into developing new or existing teaching methods, and applications can be made at all school levels across the country. Thus, even if the theoretical claims of the research were to be disregarded, the practical and qualitative results of the research cannot be denied, and the overall contribution is sound.
It is possible that different results might have been obtained with a different sample of pupils and/or with a different data collection method e.g. written questionnaire. However, the value of the study has not been to document in detail the changes in understanding with age of discrete concepts, but to show trends in pupils' thinking and possible underlying learning models.

5.7 Summary

The main conclusions from the research are summarized below, as answers to the research questions, followed by recommendations for future research.

Conclusion 1 (refer to Research Question 1: How much knowledge do students have of earthquakes/volcanoes and related events, and what is the status of their understanding of the phenomena?)

The main findings, as could be expected, are, firstly, that Senior school students have the best understanding of the science concepts, and Primary school children the lowest. Secondly, the development in between is uneven. Thirdly, many students share common ideas about earthquakes, such as 'shaking', 'waving', 'running away', and 'injuries', and in the case of volcanoes, 'lava', 'smoking', 'hole in the mountain'. Students' knowledge of earthquake/volcano and related events seems related to their areas of attention, which may alter according to first contact knowledge or first contact resources. A good example of that was a student (Appendix 4, student 06) who had seen a muddy volcano in Hua-Lien County, and who obtained more information about volcanoes because, he said, he had become more interested. The status of students' understanding about earthquakes/volcanoes and related events are not specific but rather necessarily general (as, for example, in the case of the student who knew about smoke from a volcano, but not necessarily the causes). The main reason is that focus tends to change and knowledge is partial. Key knowledge is difficult and complex, but students lose interest and transfer their focus to another possibly related area. Students' understanding of earthquakes and volcanic events seems to progress naturally according to the Rotational Learning model. The development of their understanding of earthquakes and volcanic events seems to accord naturally with their focuses - not the curriculum learning stage. Students might understand earthquakes and volcanic events in general, but there are some knowledge gaps remaining, while general understanding moves forward, which means that students' understanding might not always be as complete as teachers and examiners would wish.

Several situations occurred in my research similar to those described by Schoon (1989). For example, there was confusion between earthquakes, other natural hazards, and weather conditions appearing in some of the answers. Some students defined an earthquake as a volcano and answered affirmatively that an earthquake and a volcano are the same thing. At least one student in each study used the word "erupt" or "eruption" in a comparative description of an earthquake and a volcano, even though these words were eliminated from any of the probe questions after the early study. The most confusion in my research between earthquake and volcanoes was seen in the responses of the students in early Primary level, perhaps reflective of their being geographically close to volcanoes and earthquakes, more than students who live in the east of Taiwan where earthquakes usually happen. In the research described in Chapter 2, Italy was the only European country among research locations. Bezzi (1989) found that the students in Italy had some misconceptions about earthquakes. In contrast, students in England, for example, where I carried out my pilot study using a very similar range of questions, seemed to have almost no concrete ideas about earthquake events. This may mean that students from a similar European culture, may vary considerably in knowledge and understanding on account of differences in regional location and personal experience.

Conclusion 2 (refer to Research Question 2: What are the students' ideas concerning the relationship between earthquakes and volcanic events?)

In accordance with conclusion 1, students do not seem to have clear ideas about the relationship between earthquakes and volcanic events; most students' answers are guesses or are based on vague knowledge. Few students have clear concepts. The relationship between earthquakes and volcanic events is more complex and specific than each single event taken individually. However, the students' feedback indicates that not many of them have acquired this knowledge, as less than 10% of students gave correct answers. The relationship between earthquakes and volcanoes is a difficult one to conceptualise, and therefore it is quite a good marker to discover students' level of understanding. Knowledge and understanding of the Earth's internal structure is impeded, as the origins of events are not visible. Without a grasp of the deeper structures of knowledge, it is debatable how far a student's understanding of either phenomenon can be considered complete or "scientific".

My own findings amongst Taiwanese students are very similar to those of Ross and Shuell (1993), who likewise reported a focus amongst American children at Primary level on the immediately observable, and a tendency towards merely descriptive rather than explanatory accounts, with emphasis on "shaking" and "things falling down" and on the damage resulting from an earthquake, but little or no attempt at explanation of the event. Similarly, Leather (1987) reported a confusion amongst 11-14 year-olds regarding the role of atmospheric temperature. His informants seemed to have confused the notions of cracking of the Earth in hot countries with dry soil conditions. Leather's informants cite this as evidence and even as an explanation for a supposed phenomenon that earthquakes only occur in hot countries. This demonstrates a misconception, and vagueness regarding the causation of earthquakes.

Lillo (1994), Granda (1988) and Sharp (1995) reported on poor understanding amongst Primary school students about the internal structure of the earth, and both Sharp (1995) and Happs (1982 b) cited a poor grasp of the relationship between earthquakes and volcanoes. This poor understanding of the link between the two reflects an inability to properly or adequately understand the phenomena that underlie them.

As regards curriculum design in Taiwan, it suggests that, while "Rotational Learning" might to an extent be a useful model for students' shifting interests at Secondary Level, as I have already suggested, some "Hammering Home" might be called for at the lower levels of Secondary school as a thorough grasp of the Earth's internal structure is needed in order to develop a genuinely scientific approach.

Conclusion 3 (refer to Research Question 3: Have the students own experiences of earthquakes and volcanic events prepared them to know what to do when they happen?)

There is a noticeable difference between students who have and those who have not experienced earthquakes and volcanic events first hand, in terms of preparedness for when they happen. In general terms, students have good knowledge about what to do before and during earthquakes, but they have less idea of what to do afterwards. Students lack knowledge regarding rescue plans and the rebuilding of disaster areas. Students have good practical training in dealing with earthquakes (at least once a year). However training in dealing with volcanic events and training in what to do ***after*** an earthquake are both insufficient.

Conclusion 4 (refer to Research Question 4: Can the findings be used in curriculum development in Taiwan?)

From students' feedback and my analysis, it seems that students have already spontaneously adopted the Rotational approach to learning rather than the more monolithic learning model which the designers of the curriculum expect students to follow.

As I suggested earlier, it might be more helpful to adopt a Combinative Learning Model (CLM). At early Primary level, for example, the "Hammering Home" learning model, as I term it, might be helpful, to establish a solid and complete basis for scientific concepts, whilst at Secondary level, the curriculum should be based on students' existing scientific knowledge, allowing their interest and focus to progress according to a Rotational Learning model. The one exception I make in this regard is to do with the internal structure of the Earth, which, as I mentioned in Conclusion 2, is crucial to the development of a specifically "scientific" understanding of the phenomena, this being so central to a deeper understanding. I would suggest that Year 3 in Junior High school would be an appropriate stage, at age 14-15, when an adult grasp of the notions of causation, prediction and explanation is more widespread and better developed. At an earlier age than that, it seems that the relevant cognitive skills may not yet be sufficient. The present curriculum design, which only adopts the "Hammering Home" learning model at Primary level and Secondary level, cannot maintain students' interests or respond to their need to change focus. Curriculum designers could give thought to changing the curriculum structure.

Finally, I would like to suggest that there might be a case for further research examining students' training/instruction and immediate reactions in the face of actual earthquakes and volcanic events. I have indicated a critical limitation to my own research in that I cannot observe students' psychological state and reactions in real earthquakes and volcanic events. Secondly, I cannot find out the classroom learning results of students. Without such research, it is difficult to know how training and class learning can be effective in real-life situations. If training and classroom learning are poor, there must be real consequences and room for improvement, I believe that further research would connect naturally with the research I have done and might offer more practical assistance in saving people's lives. It might also reduce some of the blind spots in students' knowledge and understanding of earthquakes and volcanic events, both at a theoretical level as well as in more practical terms, and so contribute towards bridging the gap between the two.

Bibliography

Appleton, K.(1993) Using theory to guide practice: teaching science from a constructivist perspective. *School Science and Mathematics*,93,269-274.

Ault, C.R.(1985) Concept mapping as a study strategy in Earth Science. *Journal of College Science Teaching*, 15(Sept/Oct), 38-45.

Bezzi, A. (1989). Geology and society: A survey on pupil's ideas as an instance of a broader prospect for educational research in earth science. Paper presented at the 28th International Geological Congress, Washington,D.C.

Blaut J.M (1997) *The Mapping Abilitites of Young Children.* Annals of the Association of American Geography.

Blenis, Debra S. (2000) The Effects of Mandatory, Competitive Science, Fairs on Fifth Grade Students' Attitudes toward Science and Interests in Science. (Reports-Research, Non-Journal).

Bruner, J., Goognow, J.J. and Austin, A.A. (1956) *A study of thinking.* New York: John Wiley.

Butterworth, G., Siegal, M. and Dorfmann, M. (1997) Young children's knowledge of the shape of the Earth in England and Australia. Paper presented at the Society for Research in Child Development meeting, Washington DC, Apirl 1997. 7pp.

Callister, J.C.& Mayer, V.J.(1988). NSTA's new earth science test. *The Science Teacher*, 55(4), 32-34.

Cannell, C.F. and Kahn, R. L. (1968) Interviewing. In: G. Lindzay and E. Aronson (eds.) *The handbook of social psychology* (Vol.2). New York: Addision- Wesley. 526-595.

Catling Simon (1994) *THE GLOBE: Teacher's Notes.* London: Collins Longman Atlases.

Chen, J.C and Liu T.C (2002) *High School Earth Science textbooks.* Taipei: Nan-I Publishing House 2002 edition.

Chula, Marleyne (1998) *Adolescents' Drawings*: A View of Their Worlds. 82p; Paper presented at the Annual Meeting of the American Educational Research association (San Diego, CA, April 13-17, 1998).

Claxton, G. (1993) *Minitheories: a preliminary model for learning science.* In: P. J. Black and A.M. Lucas (eds.) Children's informal ideas in science. London: Routledge. 45-61.

Cohen, L. Manion, L. and Morrisson, K. (2000) *Research methods in education.* London: Routledge.

Cosgrove, M. and Osborne, R. (1985) *Lesson frameworks for changing children's ideas.* In: Osborne, R. and Freyberg, P(eds) Learning Science: the implications of children's science. Auckland: Heinemann. 101-111.

Cox, M (1992) *Children's drawings*. London:Penguin.

Cullinan, Bernice. (1989). *Literature and the Child*, 2nd edition. Harcourt, Brace, Jovanovitch, New York.

Dove, J. E. (1996). Student identification of rock types, *Journal of Geoscience Education*, 44, 3, 266-9.

Dove, J. E. (1997). Students ideas about weathering and erosion, *International Journal of Science Education* 19, 8, 971-80.

Dove J.E (1998) Students' alternative conceptions in Earth science: a review of research and implications for teaching and learning. *Research Paper in Education* 13(2) 1998, pp.183-201.

Dowd Frances (1990) Geography Is Children's Literature, Math, Science, Art and a Whole World of Activities. *Journal of Geography, March-April*, pp68-73.

Driver, R. (1981) Pupils' alternative frameworks in science. *European Journal of Science Education*, 3(1), 93-101.

Driver, R., Guesne, E. and Tiberghien, A. (1985) Some features of children's ideas and their implications for teaching. In: R. Driver, E. Guesne and A. Tiberghien (eds.) *Children's ideas in science*. Milton Keynes: Open University Press.193-201.

Driver, R. and Bell, B. (1986) Students, thinking and the learning of science: a constructivist view. *School Science Review*, 67, 443-456.

Driver, R. (1989) Students' conceptions and the learning of science. *International Journal of Science Education*, 11(special issue), 481-490.

Driver, R., Asoko, H., Leach, J., Mortimer, E. and Scott, P. (1994) Constructing scientific knowledge in the classroom. *Educational Researcher*, 23(7), 5-12.

Elstgeest, J. (1985) The right question at the right time. In: W. Harlen (ed.) *Primary science: taking the plunge*. London: Heinemann. 36-46.

George, J. and Glasgow, J. (1988) *Street science and conventional science in the West aphers*, 87(1), pp. 152-158.

Good, C. V. (1963) *Introduction to educational research*. New York: Appleton, Century, Crofts.

Granda, A.(1988) Esquemas conceptuales previos de los alumnus en Geologia. *Ensenaza de las Ciencias*, 6(3), 239-243.

Happs, J. C. (1982a). Rocks and Minerals (*Science Education Research Unit Working Paper 201*). Hamilton: University of Waikato, New Zealand.

Happs, J. C. (1982b). Mountains (*Science Education Research Unit Working Paper 202*). Hamilton: University of Waikato, New Zealand.

Harlen, W. (1992). Research and the development of science in the primary school. *International Journal of Science Education*, 14(5), 491-503.

Harlen, W. (2000) *The teaching of science in primary schools*. London: Fulton.

Hodson, D(1988). Toward a philosophically more valid science curriculum. *Science Education*, 72(1), 19-40.

Holt, John (1995). *How children learn. Cambridge*: Da Capo Press, 1995.

Johnson, P. and Gott, R. (1986) Constructivism and evidence from children's ideas. *Science Education*, 80(5), 561-577.

Koszalka, Tiffany A. (2001) Effect of Computer Mediated Communications on Teachers' Attitudes toward Using web Resources in the classroom. *Journal of Instructional Psychology*, v28 n2 p95-103, Jun 2001.

Larochelle, Marie (1998). *Constructivism and education*. Cambridge: Cambridge University Press, 1998.

Larson, E. E. and P.W. Birkland. (1982) *Putnam's Geology*. New York: Oxford University Press.

Leather, A. D. (1987). Views of the nature and origin of earthquakes and oil held by eleven to seventeen year olds, *Geology Teaching*, 12, 3, 102-8.

Lillo, J. (1994). An analysis of the annotated drawings of the internal structure of the Earth made by students aged 10-15 from primary and secondary schools in Spain, *Teaching Earth Science*, 19, 3, 83-7.

Moore-Hart, Margaret A. (2002) Creating a Pathway to Multicultural Education in Urban Communities: Real-Life Experiences for Pre-service Teachers. *Reading Horizons* v42 n3 p139-173, Jan-Feb 2002.

Nussbaum, J. and Novak, J.D. (1976) An assessment of children's concepts of the Earth utilizing structured interviews. *Science Education*, 60(4), 535-550.

Nussbaum, J. (1989) Classroom conceptual change: philosophical perspectives. *International Journal of Science Education*, 11(Special Issue), 530-540.

Ogborn, J. (1993) A view of 'understanding'. In: P. J. Black and A.M. Lucas (eds.) *Children's informal ideas in science*. London: Routledge. 102-119.

Osborne, J. (1980). Some aspects of the students' view of the world. *Research in Science Education*,10,11-18.

Osborne, R. and Freyberg, P. (eds.) (1985) *Learning science: the implications of children's science*. Auckland: Heinemann.

O'Shea, Marius Paul (1999) A Sociocultural Analysis of Spatial Representation in Drawings by Singaporean Children. International Society for Education through Art (InSEA)

Oversby, J. (1996) Knowledge of earth science and the potential for its development. *School Science Review*, 78, 91-7, 283-383.

Piaget, J. (1932) *The Moral Judgement of the Child*. London: Routledge and Kegan Paul.

Ross, K. E. K. and Shuell, T. J. (1993). Children's beliefs about earthquakes. *Science Education*, 77, 2, 191-205.

Rothery David A.(2000) *Teaching Yourself Geology*. Cox & Wyman Limited.

Russell, T., Bell, D., Longden, K. and McGuigan, L. (1993). *Rocks, Soil and Weather* (Primary SPACE Project Research Report). Liverpool University Press.

Ryle, G. (1949) *The concept of mind*. London: Hutchinson.

Schoon, K. J. (1989) Misconceptions in the earth sciences: a cross-age study. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching. (62nd, San Francisco, CA, 30 March-1 April, 1989)

Selley, Nick (1999). *The art of constructivist teaching in the primary school: a guide for students and teachers*. London: David Fulton, 1999.

Sharp, J. G. Mackintoch, M. A. P. and Speedhouse, P. (1995). Some comments on children's ideas about Earth structure, volcanoes, earthquakes and plates. *Teaching Earth Science*, 20, 1, 28-30.

Sharp, J., Peacock, G., Johnsey, R., Simon, S. and Smith, R. (2002) *Primary science: teaching theory and practice*. Exeter: Learning Matters.

Spivey, Nancy Nelson (1997). *The constructivist metaphor: reading, writing, and the making of meaning*. San Diego: Academic Press, 1997.

Steffe, Leslie P and Gale, J (1995) *Constructivism in education*. Hillsdale, N.J:Lawrence Erlbaum, 1995.

Symington, D., Radford, T., Boundy, K. and Walton, J. (1981) Children's drawings of natural phenomena. *Research in Science Education*, 11, 44-51.

Thamas, G.V.(1995) The role of drawing strategies and skills. In C. Lange-Kuttner and G.V. Thomas (eds) *Drawing and Looking* (pp. 107-22). Hemel Hempstead: Harvester Wheatsheaf.

Trend. R (1998) An investigation into understanding of geological time among 10- and 11-year-old children. *INT. J. SCI. EDUC*, 1998, Vol. 20, No.8, 973-988.

Tuckman, B.W. (1999) *Conducting educational research.* Fort Worth: Harcourt Brace.

Tulving, E. (1972) *Episodic and semantic memory.* In: E. Tulving and W. Donaldson (eds.) Organization of memory. London: Academic Press.

Turner, David.(1984). Reform and the physics curriculum in Britain and the United States. *Comparative Education Review* 28: 444-453.

Van Sommers, P. (1984) *Drawing and Cognition.* Cambridge University Press.

Von Glaserfeld, E. (1989) *Cognition, construction of knowledge and teaching.* Synthese, 80, 121-140.

Vosniadou, S. and Brewer, W.F. (1992) Mental models of the Earth: a study of conceptual change in childhood. *Cognitive Psychology*, 24, 535-585.

Wellington, Jerry (2000). *Educational Research: Contemporary Issues and Practical Approaches.* Biddles Ltd, Guildford and King's Lynn.

White, W.B. (1988). *Geomorphology and Hydrology of Karst Trrrains.* New York: Oxford University Press.

Wiegand Patrick (1991) Young Children's Freehand Sketch Maps of the World. *International Research in Geographical and Environmental Education.* Vol.4, No.1. pp. 19-28.

Wiegand, P. (1995) Young children's freehand maps of the world. *International Research in Geographical and Environmental Education,* 4(1), 19-28.

Wiegand Patrick (1998) Children's Free Recall Sketch Maps of the World on a Spherical Surface. *International Research in Geographical and Environmental Education.* Vol.7, No.1.

Appendix 1: The Understanding of Volcanic Events in Primary School Year 3

	0. Are volcanic eruptions predictable?	1. What is a volcano?	2. What happens during a volcanic eruption?	3. How long do volcanic eruptions last?	4. What does it look like before/during/after a volcanic eruption?	5. What causes a volcano to erupt?	6. How often do volcanic eruptions happen?	7. Where do volcanic eruptions occur?	8. Have you ever experienced a volcanic eruption?	9. Are you afraid of volcanic eruptions?	10. What should we/you do before/during/after a volcanic eruption?
Student 01 **Father and mother: Businessman** **10Y09M** **Male** **TV/film/ Video/ Book/ Comic/ Newspaper/ Magazine/ Computer**	No.	I am not clear about it.	Lava flow and earthquakes.	At least 10 minutes or more.	Before: Shaking. During: Lava flow. After: Many places get fire.	I don't know.	10 times per year.	Hawaii.	No.	Yes, I am afraid of it, because houses get burned.	I don't know.
Student 02 **Father: Businessman.** **Mother: Secondary teacher.** **10Y03M** **Male** **TV/ Video/ Newspaper/ Computer**	Yes, when volcano start to shake, it is going to erupt.	The Mountain-s which have had eruptive action.	Red lava and black smoke come out from volcanic mouth.	About 1 day.	Before: I don't know. During: I don't know. After: Whole the areas are covered by smoke.	The dry climate.	1 for every 1-2 years.	Whole world.	No.	Yes, I am afraid. Because lava will come to me very quickly, and whole area will be covered by lava.	Before: go away as far as possible. After: Stay in a safe place.
Student 03 **Father: Correspondent** **Mother: Businesswoman** **09Y06M** **Male** **TV/ Video/ Book/Newspaper/ Magazine**	No.	I don't know.	Lava flow, I think.	About 1 hour.	I don't know.	I don't know.	I am not sure.	Japan, Taiwan, Hawaii.	No.	Yes, I am afraid of lava, and I might lose my life because of it.	I don't know.

Student 04 **Father and mother: Businessman** **10Y02M** **Male** **TV/ Book/ Newspaper/**	No.	A mountain could erupt lava.	Houses are covered by lava and get burn.	I don't know.	Before: Lava level rises up slowly. During: Lava flow comes out quickly. After: Lava flows to the low land.	I don't know.	I have no ideas.	Japan.	No.	No, I think it must be exciting.	Before: Leave the volcanic area. After: Come back and re-build everything.
Student 05 **Father: Engineer** **Mother: Housewife** **10Y04M** **Female** **TV/ Video/ Comic/ Computer**	Yes, but I don't know how to predict it.	I don't know.	Lava flow.	I don't know.	Before: All the houses collapse. During: People running away. After: I don't know.	I don't know.	I have no ideas.	I don't know.	No.	No, I am not afraid, because if I can escape to a safe place, that will be fine.	I don't know.
Student 06 **Father: Businessman** **Mother: Housewife** **09Y10M** **Female** **TV/Book/newspaper.**	No.	I am not sure what that is, but Mt. Fuji is a volcano. (This student understands Mt. Fuji is a volcano from language textbook)	Lava flow, and stone falling down.	About 5 minutes.	Before: Shaking. During: Lava comes out. After: There are a lot of stone all over ground.	I don't know.	I don't know.	I don't know.	No.	Yes, I am afraid if stones would hit me.	I don't know.
Student 07 **Farther: Businessman** **Mother: Service trade** **09Y11M** **Female** **TV/film/ Video/ Book/ Comic/ Newspaper/**	No.	A mountain could erupt lava.	Lava flow and hailstones.	It takes 1 day.	Before; Shaking. During: Lava flow. After: Lava get cold and cover the road.	I don't know.	I am not sure.	Canada and Australia.	No.	Yes, I am afraid of it, because I have no experience about it, therefore, I can not handle the situation, I don't know how to escape, and I don't know how to run away.	Before: Clean up the house for running to the door as soon as possible. After: Ask fire-fighter for help.

Student 08 **Father and mother: Unknowing job.** **10Y00M** **Male** **TV/ book/ newspaper**	No.	A mountain is with fire inside.	Mud flow.	Quite long, about 2 year.	I don't know.	I have no ideas.	I have no ideas.	I don't know.	No.	Yes, I am afraid of it.	I don't know.
Student 09 **Father and mother: Secondary teacher.** **09Y11M** **Male** **TV/book/ Magazine**	Yes, when heat comes up, it might erupt.	A mountain could erupt lava and a lot of hot rocks.	I think most rocks will burn.	I don't know.	Before: Volcanic mouth split. During: Here comes lava flow. After: Lava gets cold and then becomes rocks.	I don't know.	I don't know.	Japan.	No.	Yes, I am afraid if I will be burned to death.	I have no ideas.
Student 10 **Father and mother: Businessman.** **09Y08M** **Male** **TV/film/ Book/ Comic/ Newspaper/**	No.	I don't know what volcano is very well, but I know Mt. Fuji is a volcano. (This student understands Mt. Fuji is a volcano from language textbook).	Here comes earthquakes first, and then is lava flow, finally the stone split.	It takes few minutes.	Before: Earthquakes. During: Lava flow. After: Ground becomes very dark.	Something hits the bottom of volcanoes in the deep sea.	It takes few years.	I don't know.	No.	Yes. Because everything will be destroyed.	I don't know, I have no experience.
Student 11 **Father: Businessman** **Mother: Housewife** **09Y10M** **Male** **TV/ Video/ Book/ Comic/ Magazine**	No.	No ideas.	Lava flow.	I don't know.	Before: I don't know. During: Lava floe comes out. After: I don't know.	I don't know.	1 for every 10 years.	Japan.	No.	Yes, I am afraid of heat and fire.	Before: I don't know. After: To put out fire.

Student 12 **Father and mother: Businessman.** **09Y00M** **Male** **Film/ Video/ Book/ Newspaper/ Magazine**	No.	No ideas.	Lava flow and smoking	It takes few hours.	Before: Few lava comes out. During: A lot of lava comes out. After: A lot of smoking comes out.	I don't know.	1 for few months.	Australia and USA.	No.	Yes, I am afraid of lava flow.	I don't know.
Student 13 **Father: Businessman** **Mother: Housewife** **09Y05M** **Female** **TV/film/ Book/ Newspaper/ Computer**	No.	A mountain could erupt lava.	Smoking and lava.	It takes 10 minutes.	Before: I don't know. During: Lava and smoking come out. After: Cold lava become rocks.	I don't know.	I don't know.	Japan and Taiwan.	No.	Yes, I am afraid of lava, because lava is very hot.	I don't know.
Student 14 **Father: Designer** **Mother: Housewife** **09Y03M** **Female** **TV/ Book/ Newspaper/ computer**	No.	A terrible mountain which contains lava.	Lava flow and smoking.	I don't know.	I don't know.	I don't know.	I don't know.	Taiwan and India.	No.	Yes, I am afraid of lava, it is very hot.	I don't know.
Student 15 **Father and mother: Secondary teacher** **09Y08M** **Female** **TV/film/ Video/ Book/ Newspaper/ computer**	No.	A mountain could erupt lava.	Mountains are red, because lava flow has already covered them.	It takes about 2 hours.	Before: Shaking. During: Lava flow. After: Ground will be still hot.	I don't know.	I don't know.	Japan.	No.	Yes, I am afraid, because lava can make me as a homeless.	I don't know.

Student 16 **Father and mother: Unknown jobs** **09Y08M** **Female** **TV/ newspaper/ computer**	No.	A mountai n someti mes erupts lava.	Fire is everywhere .	2-3 minutes.	Before: I don't know. During: Fire is everywhere. After: I don't know.	I don't know.	I don't know.	Japan.	No.	Yes, I am afraid, because fire is very hot.	I don't know.
Student 17 **Father and mother: Businessman.** **09Y07M** **Female** **TV/book/ Newspaper/ Computer.**	No.	No ideas.	I don't know.	I don't know.	I don't know.	I don't know.	I don't know.	I don't know.	No.	Yes, I am afraid.	I don't know.
Student 18 **Father: Businessman.** **Mother: Housewife.** **Y0910M** **Female** **TV/ Book/ newspaper**	Yes, but I don't know by how.	A mountai n is with fire inside.	Smoking and stone are everywhere .	I don't know.	Before: I don't know. During: Smoking and stone are everywhere. After: There are a lot of rocks and stones on the ground.	I don't know.	I don't know.	Japan.	No.	Yes, I am afraid if stone hit my head.	I don't know.
Student 19 **parents: pass away.** **Uncle: Chef** **Aunt: Housewife** **09Y06M** **Female** **TV/film/ Video/ Book/ Newspaper/ Magazine**	I don't know if it is predictabl e.	I don't know.	A mountain spit fire out.	I don't know.	Before: Earthquakes. During: A lot of fire. After: I don't know.	I don't know.	I don't know.	Japan.	No.	Yes, I am afraid if fire would burn me.	I don't know.

Student 20 **Father and mother: Businessman** **09Y06M** **Female** **TV/film/ Book**	No.	No ideas.	Lava	I don't know.	I don't know.	I don't know.	I don't know.	I don't know.	No.	Yes, because lava is so hot.	I don't know.
Student 21 **Father: Worker** **Mother: Catering trade.** **09Y05M** **Female** **TV/ Book**	I don't know.	A mountain could erupt lava and shake heavily.	Hose temperature will rise up. Because lava is hot.	1 day.	Before: I don't know. During: There are a lot of lava and smoking. After: I don't know.	I don't know.	I don't know.	Japan, USA, New Zealand, and Australia.	No.	Yes, lava and heat can burn me.	I don't know.
Student 22 **Father: Self-employer** **Mother: Service trade** **09Y01M** **Female** **TV/film/ Book**	No.	A mountain contains lava.	Lava and stone are everywhere.	I don't know, but it takes a long time, I guess.	Before: I don't know. During: Lava comes out. After: Lava starts to become rocks.	I don't know.	I don't know.	Japan.	No.	Yes, I am afraid of lava, because it is hot.	Before: I don't know. After: I will move out of the area.
Student 23 **Father: Military officer** **Mother: Nurse** **09Y08M** **Female** **TV/book/ Newspaper/ Magazine**	No.	Mt. Fuji is a volcano. (This student understands Mt. Fuji is a volcano from language textbook)	Red lava is all over the place.	It takes few hours.	Before: It just erupts a little bit lava. During: A lot of lava comes out. After: Many people lose their lives.	I don't know.	I don't know.	Japan and Taiwan.	No.	Yes, I am afraid of lava.	I don't know.

Student 24 **Father and mother: Unknown jobs** **09Y08M Female** **TV/film/ Video/ Newspaper/ Magazine/ computer**	No.	A mountai n can spit fire.	Fire is everywhere .	I don't know.	I don't know.	I don't know.	I don't know.	Japan and USA.	No.	Yes, I am afraid of it.	I don't know.
Student 25 **Father and mother: Business Company staffs.** **09Y00M Female** **TV/book**	No.	No ideas.	Fire is everywhere .	I don't know.	Before: Volcanoes have some smoking. During: Volcanoes have strong fire. After: I don't know.	I don't know.	I don't know.	I don't know.	No.	Yes, I am afraid of it.	I have no ideas.

Appendix 2: The understanding of Volcanic Events in Primary School Year 6

	0. Are volcanic eruptions predictable?	1. What is a volcano?	2. What happens during a volcanic eruption?	3. How long do volcanic eruptions last?	4. What does it look like before/during/after a volcanic eruption?	5. What causes a volcano to erupt?	6. How often do volcanic eruptions happen?	7. Where do volcanic eruptions occur?	8. Have you ever experienced a volcanic eruption?	9. Are you afraid of volcanic eruptions?	10. What should we/you do before/during/after a volcanic eruption?
Student 01 **Father: Technician** **Mother: Housewife** **12Y08M** **Male** **TV/film/ Video/ Book/ newspaper**	No.	A mountain could erupt lava and ash.	lava flow, everything get burn.	It takes few minutes.	Before: Temperature rise up. During: Lava floe comes up, everything get burn. After: Ground becomes black, because it is damaged by lava.	This is because Earth try to release its extra energy.	1 for 3-4 years.	Japan, Taiwan, China, Canada and USA.	No.	Yes, I am afraid of it, because lava is very hot.	Before: Try to evacuate everyone. During: Run away from the area. After: Ask government to re- build the area.
Student 02 **Father: Public servant.** **Mother: Housewife** **12Y08M** **Male** **TV/film/ Video/ Book/ Newspaper/ Magazine/ Computer**	It is possible to predict the volcanic eruption by shaking and smoking detection.	Lava comes out from thinner Earth crust.	Lava flow and rocks	In 1 minute.	Before: There is only little lava comes out. During: Volcanoes spit a lot of lava. After: Lava get cold and turn to igneous rock.	I don't know.	It really depends.	Japan, Taiwan, China, and Hawaii.	No.	Yes, I am afraid of rocks and lava.	Before: Try to run away to the high mountains. During: The same as above. After: Waite until everything get cold.
Student 03 **Father: Driver** **Mother: Housewife** **12Y08M** **Male** **TV/ Video/ Book/ Newspaper/ Magazine computer**	I am not sure.	A mountain contains lava.	I don't know.	I don't know.	Before: Shaking. During: Shaking becomes stronger. After: I don't know.	I don't know.	About half year.	Taiwan, Philippines, Madagasgar, north Africa, Hawaii, America.	No.	Yes, because heat hurts people.	I don't know.

Student 04 **Father and mother: Technician** **12Y08M** **Female** **TV/film/ Video/ Book/comic/ Newspaper/ Computer**	No.	A mountain could erupt lava.	Lava flow, volcanic ash, smoking and rocks.	It depends.	Before: I don't know. During: Lava, volcanic ash in the air. After: Volcanic ash on the ground.	I don't know.	I don't know.	Japan, Taiwan and North America.	No.	Yes, I am afraid of volcanic ash and lava.	I don't know.
Student 05 **Father: Business.** **Mother: Lawyer** **12Y08M** **Male** **TV/ Book/ Newspaper/ Magazine/ computer**	No.	No ideas.	Lava flow and mud flow.	I don't know.	I don't know.	I don't know.	I don't know.	Japan, and Taiwan.	No.	Yes, I am afraid of heat.	I don't know.
Student 06 **Father: Chef** **Mother: Nurse** **12Y07M** **Male** **TV/ Video/ Book/ Newspaper/ computer**	Yes, by detecting shaking of volcano, when it shake heavily, it is going to erupt.	There are too many energy in the Earth core, and where the energy come out is called volcano.	Volcanic ash and lava.	About few hours.	I don't know.	I don't know.	1 for 2-3 years.	Taiwan and Madagasgar.	No.	Yes, I am afraid of heat.	I don't know.
Student 07 **Father: Sales** **Mother: Housewife** **13Y07M** **Male** **TV/film/ book/ newspaper computer**	No.	A mountain is always smoking.	Lava flow.	It takes few hours.	Before: Just a little lava comes out. During: A lot of lava comes out. After: Lava get cold and becomes rocks.	I don't know.	It depends.	Japan, Taiwan, Australia and USA.	No.	Yes, I am afraid of Lava.	Before: Making a strong and long wall to stop lava flow. During: Using water to cool down lava. After: Remove the cold lava from road.

Student 08 **Father and Mother: Unknown jobs** **12Y04M Male** **TV/film/ Video/ Book/comic/ magazine**	No ideas.	A mountain could erupt lava.	Lava and volcanic ash.	It all depends.	Before: Earthquakes. During: Lava flow comes out. After: I don't know.	I don't know.	It all depends.	Japan, Taiwan and Hawaii.	No.	Yes, I am afraid of lava, because it is too hot.	Before: Escape from disaster area. During: Keep running. After: Ask help from government.
Student 09 **Father: Engineer** **Mother: Housewife** **12Y04M Male** **TV/film/ Video/ Book/ Comic/ magazine newspaper computer**	No.	No ideas.	Lava comes out and volcanic ash as well.	It all depends.	I don't know.	I don't know.	It all depends.	Japan, Taiwan, China, USA and Hawaii.	No.	Yes, I am afraid, especially lava.	Before: To learn how to have a quick reaction. During: Evacuate all people. After: Test and verify if escaping plan is a proper plan.
Student 10 **Father: Security Guard** **Mother: Pass away.** **12Y01M Male** **TV/film/ Video**	Yes, because every volcano has its own eruptive cycle.	A mountain is with a hole in the center of top and contains lava inside.	Volcanoes spit lava into very high position.	From few hours to few days.	Before: Earthquakes. During: People leave because lava comes out. After: Re-build the disaster area.	Earthquakes.	It all depends.	Japan, Taiwan Australia, China, Middle East, south America and North America.	No.	Yes, I am afraid of heat.	Before: Try to probe the eruption as accurate as possible. During: Evacuate all people. After:\try to re-build the area.
Student 11 **Father: Designer** **Mother: Bank staff.** **13Y 01M Male** **TV/film/ Video/ magazine newspaper Computer**	Yes, when lava flows much quick than usual, it might erupt.	A mountain is with a hole in the center of top and without any tree and rock.	There are very thick smoking and lava.	About few hours.	Before: Earthquakes. During: Smoking and lava. After: Everything get burn and lava starts to become rock.	I don't know.	1 for every 10 years.	Japan, China and Africa.	No.	Yes, because lava is so hot.	Before: Fire brigade should keep spiting water. During: Everybody should run away. After: Try to re-build the area.

Student 12 **Father: Self-employer Mother: Housewife.** **13Y00M Female** **TV/book/ Comic**	Yes, I think so, but I don't know by how.	A mountai n could erupt lava.	Smoking, lava and fire are everywhere .	I don't know.	Before: I don't know. During: Volcanoes erupt, and many things fly out. After: Many people are dead, and there are a lot of volcanic ashes.	I don't know.	It all depends.	Taiwan, China and Hawaii.	No.	Yes, I am afraid of fire.	I don't know.
Student 13 **Father: Self-employer Mother: Housewife** **12Y11M Male** **TV/film/book ? Newspaper/ computer**	Yes, but I don't know how to predict it.	A mountai n spits fire irregula rly.	Lava flow, volcanic bomb and earthquake s.	About 3 hours.	Before: A lot of shaking. During: Lava comes out. After: Fire brigade come to help.	I don't know.	I don't know.	Japan, Taiwan, and Hawaii.	No.	Yes, I am afraid of lava, it is too hot.	Before: Evacuate people as soon as possible. During: Fire brigade should spray water on the lava. After: Try to help Other people.
Student 14 **Father and mother: Beauty shop owner.** **13Y09M Female** **TV/book/ Magazine/ computer**	No.	A mountai n contains lava inside.	Ground shaking, Heat and lava.	I am not sure.	Before: Ground shaking. During: Volcanoes spit lava out. After: Earth surface changed.	I don't know.	I am not sure.	South and North America.	No.	No, I am not afraid of it, because I have no sense about it.	I don't know.
Student 15 **Father: Public servant Mother: Unknown job** **12Y10M Male** **TV/film/ Book/ newspaper computer**	No.	No ideas.	There is a lot of smoke.	I am not sure.	I don't know.	I don't know.	It all depends.	Japan, Taiwan and China.	No.	Yes, I am afraid of lava.	I don't know.

Student 16 **Father: Taxi driver** **Mother: Technician** **13Y05M** **Female** **TV/film** **Video/** **Book/** **Comic/** **Newspaper/** **Magazine/** **computer**	No.	A mountain could erupt lava.	Red lava flow, it is quite hot.	I am not sure.	Before: Animals have extraordinary reaction. During: Here comes heat, and ground leaks. After: Plants are dead.	I don't know.	I am not sure.	Far East, Australia, and America.	No.	no, nothing to be afraid of.	Before: Prepare enough food and necessities. During: Go to safe place. After: Donate money to they people who live in disaster area.
Student 17 **Father: A staff in radio company.** **Mother: Primary school teacher.** **12Y09M** **Male** **TV/film** **Video/** **Book/** **Newspaper/** **Magazine** **Computer**	Yes, I think so, but I don't know by how.	A mountain could erupt lava.	Lava flow and volcanic ash.	I don't know.	I don't know.	I don't know.	It all depends.	Far East, Middle East, and USA.	No.	NO, I am not afraid of it, because if I can run away, that will be fine.	Before: Prepare water and food. During: Try to run away as far as possible. After: Move to a safe place.
Student 18 **Father and mother: Businessman** **12Y05M** **Female** **TV/film** **Video/** **Book/** **Newspaper/** **Magazine/** **Computer**	No.	A mountain contains lava inside and waiting for eruption.	Volcanic ash, lava flow.	About 1-2 days.	Before: earthquakes. During: Hot air and volcanic ash cover sky. After: Cold lava fill with basin.	Plate tectonic.	10-100 years.	Japan, Taiwan, China and Hawaii.	No.	No, I am not afraid of it, because this is a kind of natural phenomena.	Before: Get far away from volcanoes. During: Evacuate people in order. After: Limited any building in disaster area.

Student 19 **Father: Designer. Mother: Housewife.** **12Y05M Female** **TV/film Video/ Book/ Newspaper/ Magazine/ computer**	It is possible, but I don't know how to do it.	A mountain *spits* fire irregularly.	There is a lot of fire.	I don't know.	I don't know.	I don't know.	I am not sure.	Taiwan.	No.	I am not so afraid, because I don't think this will happen to me.	Before: Get away from volcanoes. During: The same as above. After: Never come back.
Student 20 **Father: Self-employer Mother: Housewife.** **12Y04M Female** **TV/film Video/ Book/ Newspaper/ computer**	Yes, when shaking frequency goes up, it might erupt.	A mountain contains lava inside and shaking heavily when it erupts.	Threes will dry off and lava is everywhere.	About in 1 hour.	Before: Lava rolling inside volcanoes. During: Lava flow comes out. After: Lava flow gets cold and starts to become rocks.	I don't know.	I don't know.	Japan and Taiwan.	No.	Yes, I am afraid of lava, because it is too hot.	Before: evacuate people as far as possible. During: Stand along the wall, because walls can stop lava flow for a while. After: Never allow people to build any house in the area.
Student 21 **Father And Mother: Businessman** **13Y01M Female** **TV/film Video/ Book/ Newspaper/ Magazine computer**	No.	No ideas.	Lava flow.	I don't know.	I don't know.	I don't know.	I don't know.	I don't know.	No.	Yes, I am afraid of lava, because lava is hot.	I don't know.
Student 22 **Father: No job. Mother: Bakery staff.** **12Y03M Male** **TV/film/ Book Newspaper Computer**	Yes, but I don't know by how.	No ideas.	Lava flow, volcanic ash and flying stone.	I don't know.	Before: Lava comes out. During: Stones fly out. After: Volcanic ashes are everywhere.	I don't know.	I don't know.	Japan and China.	No.	No, because I have no feeling about it.	All I can do is escape.

Student 23 **Father:** **No job** **Mother:** **Worker.** **11Y10M** **Female** **Film** **Video/** **Book/** **Newspaper/** **computer**	Yes, when the volcanic temperatu re goes up, it might erupt.	No ideas.	Lava flow and volcanic ash.	It takes few hours.	I don't know.	When weather becomes hot, lava will comes out.	1 for few years.	Taiwan and Middle East.	No.	Yes, because lava is too hot.	Before: Evacuate all people. During: Go to high land. After: I don't know.
Student 24 **Father:** **Service trade** **Mother:** **Housewife** **12Y07M** **Female** **TV/book/** **Newspaper**	Yes, when lava position goes up, it might erupt.	A mountai n could erupt lava.	Lava flow and people are running.	I don't know.	I don't know.	I don't know.	I don't know.	Taiwan and Japan.	No.	Yes, because lava is hot.	I don't know.
Student 25 **father and mother:** **businessman** **12Y11M** **Female** **TV/film** **Video/** **Book/** **Comic/** **Newspaper/** **Magazine/** **computer**	Yes, but only when lava nearly come out of volcano, so it is very short time to predict.	No ideas.	Lava flow.	I don't know.	I don't know.	I don't know.	I don't know.	I don't know.	No.	Yes, because lava is too hot and volcanic ash will cover me.	I don't know.

Appendix 3: The Understanding of Volcanic Events in Junior High School Year 3

	0. Are volcanic eruptions predictable?	1. What is a volcano?	2. What happens during a volcanic eruption?	3. How long do volcanic eruptions last?	4. What does it look like before/during/after a volcanic eruption?	5. What causes a volcano to erupt?	6. How often do volcanic eruptions happen?	7. Where do volcanic eruptions occur?	8. Have you ever experienced a volcanic eruption?	9. Are you afraid of volcanic eruptions?	10. What should we/you do before/during/after a volcanic eruption?
Student 01 **Father and mother: Businessman** **15Y01M** **Male** **TV/Film/ Video/ Book/ Newspaper/ computer**	Yes, by detecting smoke and shaking.	Volcano is a particular location where lava penetrates earth crust.	Lava spits out or flow all around, there are also volcanic ash and volcanic bomb.	I am not sure.	Before: There is some earth tremors. During: Volcano spits out lava. After: I am not sure.	I am not sure.	I don't know.	Japan, Taiwan and Philippines.	No.	Yes, I am afraid of it, because I will lose my life in a second, and losing my money as well.	I have no ideas.
Student 02 **Father: Printing press staff.** **Mother: Housewife.** **15Y05M** **Male** **TV/film/ Video/ Book/ Comic/ Newspaper/ Magazine/ Computer**	I don't think so, but I don't know why not.	Mountains which are usually with fire. There is a hole on the top of mountain and the hole spits fire and smoke.	Flowing lava.	I have no experience, I don't know.	I have no ideas.	When the weather and terrestrial become very hot, the volcanoes might erupt. So it has more chance to erupt in hot countries than cold countries.	I don't know.	Hawaii.	No, never.	Yes, because I think volcanic eruption is more powerful than earthquakes.	Before: I think we should surround volcanic mouth by hard material. After: To take apart all the damage building and leave the area.
Student 03 **Father: Business** **Mother: Housewife** **15Y06M** **Male** **TV/ Book/ Newspaper/ Magazine Computer**	I am not sure because I have never experienced volcanic eruption.	Volcanoes are where lava come out. (This student can not explain what is lava)	Volcanoes spit out a lot of lava.	It takes few days.	Before: Earthquakes. During: Volcanoes spit out lava. After: Lava becomes rocks.	I don't know.	1 for Every hundred years.	Japan, South Asia, and mid-America.	No.	Yes, I think it is more power than a earthquake, but realize it from watching film.	Before: I don't know. After: Try to help somebody.

Student 04 **Father and mother: Businessman** **14Y09M Female** **TV/book/ Computer**	Yes, especially when terrestrial heat goes up.	A special structure where *original* form lava, this structure normally happens in where faults split open.	Volcanic ash, animals are *running* away, and hot lava flow.	About 1 week.	Before: Earthquakes happen. During: Lava comes out from lava. After: Volcanic ash cover all the things in radius 2 Km.	Layers can not afford the rising stress from lava flow, therefore, the layers break up.	10 times per year.	Japan, India, East Africa, North and South America.	No.	Yes, I am afraid of it, especially lava is too hot, I will lose my life, and I think volcanoes are more powerful than earthquakes.	Run away all the time.
Student 05 **Father: Police officer** **Mother: Nurse** **14Y06M Male** **Book/ Magazine/Computer**	Yes, before volcanic eruption is going to occur, it is normally with earthquakes in advance. Besides, animals usually have extraordinary behavior, for example, ants will move to higher place before volcanic eruption occurs.	This is the place where lava invade crust, and it might eruption at anytime.	There are a lot of smoking and lava flow.	About half hour.	Before: There are some earthquakes. During: Lava flow comes out. After: Volcanoes will become smaller and shorter.	The movements of faults cause lava to flow from deep Earth to the surface.	20-30 times per year.	Taiwan, Malaysia, Italy and Hawaii.	No.	No, I am not afraid of it, because there is no way to run to, so being afraid is useless.	Before: Train people how to escape from the area. During: Go to the high land. After: Re-build the area.
Student 06 **Father and mother: Businessman** **14Y08M Female** **TV/video/ Book/ Magazine Computer**	Yes, we can observe the speed of lava flow, when it goes quicker, volcano might erupt.	A mountain which can spit lava.	People are running and lava flows so fast.	No ideas.	No ideas.	No ideas.	No ideas.	Japan and Taiwan.	No.	Yes, I am afraid of heat.	I don't know.

Student 07 **Father: Service trade** **Mother: Housewife** **15Y07M** **Female** **TV/film/ Video/ Book/ Newspaper/ Magazine computer**	No.	I don't know how to explain it.	Lava flow is everywhere.	About 1 minute.	I don't know.	Lava become too hot, boil, and then creates a huge pressure to erupt.	1 for every 3 years.	Taiwan, Japan and Italy.	No.	No, I am not afraid, I have handed over my life to God.	I don't know.
Student 08 **Father: No job** **Mother: Businesswoman** **15Y02M** **Female** **TV/Film/ Video/ Book/ Comic/ Newspaper/ Magazine/ Computer**	Yes, we can detect the condition of lava flow by equipment, when it goes quicker, volcano might erupt.	Mountains contain lava.	Everything is melted, no one can stop it.	About in 1 hour.	Before: Volcanic ash. During: Lava flow. After: Lava gets colder and form s as rocks.	Plate tectonic.	I don't know.	USA and Italy.	No.	Yes, I am, and I think it is more terrible than earthquakes.	Before: Always keep my eye on the volcanoes. After: Government should re-build the area.
Student 09 **Father and mother: Businessman.** **15Y08M** **Male** **TV/Book/ Computer**	Yes, when earthquakes happen more often than usual, it may have an eruption.	In Earth surface where rise up hill or mound with high temperature. With or without lava is not the key point.	There are earthquakes, volcanic ash, fire and lava flow.	Its about 3-4 hours.	Before: Ground shaking. During: Lava flow. After: Volcanic ash is everywhere.	The movement of layer.	4-5 times per year.	Japan, South Pacific Ocean, Middle East, East Africa, and USA.	No.	Yes, I am afraid of it, especially when it cause earthquakes and heat, volcanoes are more terrible than earthquakes, I think.	Before: Predict the movements as many times as possible. After: Re- build the area.

Student 10 **Father: No job** **Mother: Factory staff.** **15Y08M** **Female** **TV/film/Video/ Book/ Newspaper/ computer**	Yes, by detecting earth shaking, smoking and temperature, when they become high frequency, volcano might erupt.	Mountains which are formed by plates hitting and rising up Earth surface, volcanoes contain lava flow.	Sky becomes dark, smoke and lava are all over the place. People are panic and running away.	It takes 2-3 days.	Before: There are a lot of smoking and the temperature rise up. During: There are lava and hot stone. After: Most place are covered by volcanic ash.	The movements of faults and earthquakes.	1 for every 2-3 years.	South-East Asia, Iceland, Peru and Argentina.	No.	Yes, I am afraid, because that might be the end of my day, I am mostly afraid of lava and heat. For me, the power of volcano and earthquakes are about the same.	Before: Make an emergency plan for escape. After: I don't know.
Student 11 **Father and mother: Public servant** **15Y09M** **Female** **TV/film/video /book Newspaper/ computer**	Yes, we can see volcano swells up, and spits a lot of smoke.	I don't know.	There are lava flow and air pollution.	No ideas.	I don't know.	Plate tectonic.	1 for every 2 years.	Japan, Taiwan and South America.	No.	Yes, I am afraid of it, especially lava and volcanic ash.	Before: There is no one should be allowed to live in any volcanic area. After: try to help and save other people.
Student 12 **Father: Businessman** **No mother** **15Y02M** **Male** **TV/film/ Video/ Book/ Newspaper/ Magazine/ Computer**	Yes, by detecting volcanic activity.	I don't know.	Volcanic ash, lava flow, ground shaking.	It takes few hours.	Before: I am not sure. During: Volcanic ash. Lava flow and ground shaking. After: I am not sure.	Plate tectonic.	Less than 10 times per year.	Japan, Taiwan and Italy.	No.	Yes, I am afraid of heat and volcanic ash.	Before: Evacuate everyone. After: Re-build the area.

Student 13 **Father: Engineer** **Mother: Nurse** **15Y04M** **Male** **TV/film/ Video/ Book/ Newspaper**	Yes, by observing earth shaking.	Where lava spits out.	There are lava flow, volcanic ash and sulfuric acid.	About 1-2 weeks.	Before: Earth shaking, and weather become hotter than usual. During: Volcanic ash, lava and earthquakes. After: Volcanic glass.	Plate tectonic.	I am not sure.	Iceland, Canada, and USA.	No.	Yes, I am afraid of lava and heat, because I may lose my life by touching them.	Before: Observe the frequency of shaking and evacuate the residents. After: Re-build the area and try to find out when is next time.
Student 14 **Father and Mother: Teacher** **15Y07M** **Male** **TV/film/ Video/ Book/ Newspaper**	Yes, by observing earth shaking.	Where lava and ashes spits out. Usually with shaking.	Lava flow, volcanic ash and people are running.	It takes 1-2 weeks.	Before: There are some shakings. During: Volcanic lava. After: When lava get coder, it starts to become rocks.	Plate tectonic.	1-2 times per year.	Italy and Pacific Ocean.	No.	Yes, I am afraid of it, because volcanic ash and heat may take my life away.	Before: Notice if the layers have any moving action. After: Do some helps and assistances.
Student 15 **Father and mother: Service trade.** **15Y00M** **Female** **TV/film/ Video/ Book/ Newspaper/ computer**	Yes, before volcanic eruptions are going to happen, there will be a lot of smoking.	A mountain can spit out lava.	Volcanic ash, mud flow and lava flow.	I don't know.	I don't know.	I don't know.	2-3 times per year.	I don't know.	No.	Yes, I am afraid of heat.	I don't know.
Student 16 **Father: Businessman** **Mother: Service trade** **14Y10M** **Female** **TV/film/ Video/ Book/ Newspaper/ Magazine/**	Yes, by detecting smoking.	Earth surface where contains a hole and lava inside.	There could be smoking, lava, mud flow, and volcanic ash.	About 7-8 hours.	Before: There are some smoking. During: Here comes lava flow. After: Volcanic ash is everywhere.	I don't know.	3-4 times per year.	Taiwan, Japan, USA, and Hawaii.	No.	Yes, I am afraid of Lava (heat) and Volcanic ash (bad for health).	Before: Evacuate everybody. After: Re-construct the damage area.

Computer											
Student 17 **Father: Businessman. Mother: Housewife.** **15Y03M Male** **TV/film/ Book/ Newspaper/ Magazine/ computer**	Yes, earth shaking will be more serious before volcanic eruption starts.	A mountain can spit out lava.	There should be Carbon dioxide, mud flow, Nitrogen and lava.	I don't know.	Before: shaking, and ground water become hotter. During: Lava flow. After: A lot of smoking.	Plate tectonic.	2-3 times per year.	Taiwan , Japan, Africa, and North America.	No.	Yea, I am afraid of heat.	Before: Read the probative data carefully. After: I don't know.
Student 18 **Father and mother: Businessman** **14Y 03M Male** **TV/film/ Book/ Newspaper/ computer**	Yes, the sulfur steam will increase before eruption.	Layers are pushed by geologica l power, this process cause the lava comes out Earth surface, when lava getting colder, it solidify and piled up as a volcano.	I think dogs will bark loudly.	I don't know.	Before: There are a lot of earthquakes. During: Ground shaking and lava flow happen all the time. After: Lava become colder and starts to become rocks, at the sometime, air temperature will rise up again.	Different plates push lava out of Earth surface.	I am not sure.	In the Pacific ocean and Atlantic Ocean.	No.	Yes, a little bit, especially lava and heat, they can take my life easily.	Before: We should set some observatories near by volcanoes, and put the instruments nearby volcanic mouth. During: Try to lead lava to the sea. After: Re-build the area.
Student 19 **Father: A staff in insurance company Mother: Housewife** **15Y05M Male** **TV/ Book/ Magazine/ computer**	Yes, earth shaking will increase.	Mountain s can spit out lava.	There are full of lava flow and volcanic ash cover more than half sky.	About few days.	Before: Ground shaking. During: Volcanoes spit lava. After: Cities disappear.	Plate tectonic.	Very few, about 1 for hundred.	Australia, Hawaii, and Iceland.	No.	Yes, I am afraid that volcanic ash could cover whole city.	Before: Go away as far as possible. After: If it is safe come back, if not, never come back again.

Student 20 **Father: Self-employer** **Mother: Housewife.** **15Y03MFemale** **Book**	No.	I don't know.	I only know lava.	I don't know.	I don't know.	I don't know.	I don't know.	I don't know.	No.	Yes, because lava and heat may kill me.	I don't know.
Student 21 **Father: Self-employer** **Mother: Secretary** **14Y11M Male** **Book/ Computer**	Yes, but I don't know how.	Mountains can spit out lava.	Lava and dark cloud.	At least 10 minutes.	I don't know.	I forget.	I don't know.	I don't know.	No.	Yes, especially lava and heat.	I don't know.
Student 22 **Father: Worker** **Mother: Certified account.** **15Y01M Male** **TV/film/video / Book/ Newspaper/ Magazine/ computer**	Yes, but I am not sure how to do so.	The underground matters are heated by earth energy then become lava, and where lava spit out is called volcano.	Everywhere get fire by lava flow.	About in 1 hour.	Before: I don't know. During: Lava comes out and everything gets burn. After: Everything is burned out.	I don't know.	1 for every 10 year or more longer.	I am not sure.	No.	Yes, lava and heat can take my life.	Before: I don't know. After: Stop lava flow and try to lead lava flow to a open water.
Student 23 **Father: Salesman** **Mother: Certified account.** **14Y11M Female** **TV/video/ Book/ Newspaper**	No.	The plates movements push lava out of Earth surface where is called volcano.	Lava flow and many places get fire.	I don't know.	Before: I don't know. During: Lava flow is everywhere. After: Everything is damaged, and cold lava is all over the place.	I don't know.	I don't know.	The circle of Pacific Ocean.	No.	Yes, I am afraid of lava an heat, because these two things can cause fire.	I don't know.

Student 24 **Father: Technician** **Mother: Interpreter** **15Y03M** **Female** **TV/film/video / Book/ Newspaper/ computer**	Yes, when temperature rise up, the volcanic eruption might happen.	Asthenosphere causes crusts moving around inside the Earth, and this movement causes shaking and spiting lava.	Volcanic ash, lava flow, and tsunami.	About 1 day.	Before: Animals have different reaction than usual. During : A big sound, lava flow and volcanic ash. After: Most ashes are in the sky.	This is about the movements of asthenosphere.	1-2 times per year.	Taiwan and Hawaii.	No.	Yes, lava will cover everything.	Before: Evacuate all the people. After: Waite until lava get cold and start to tidy up the area.
Student 25 **Father: Businessman** **Mother: Certified account.** **15Y00M** **Female** **TV/book/ Newspaper/ computer**	Yes, smoking will increase before eruption happen.	Earth internal heat convection causes the movement of lava flow, it comes out in the weak point of crust.	Volcanic ash, smoke, and lava.	It takes few hours.	Before: A lot of earthquakes and smoking. During: Lava flow. After: Cold lava start to become rocks.	Earth internal heat convection.	2-3 times per year.	Italy and Taiwan.	No.	Yes, because I know lava can cover everything.	Before: Evacuate all the people. Try to help somebody and finally clan up the area if it is possible.

Appendix 4: The understanding of Volcanic Events in Senior High School Year 3

	0. Are volcanic eruptions predictable?	1. What is a volcano?	2. What happens during a volcanic eruption?	3. How long do volcanic eruptions last?	4. What does it look like before/during/after a volcanic eruption?	5. What causes a volcano to erupt?	6. How often do volcanic eruptions happen?	7. Where do volcanic eruptions occur?	8. Have you ever experienced a volcanic eruption?	9. Are you afraid of volcanic eruptions?	10. What should we/you do before/during/after a volcanic eruption?
Student 01 **Father: Government worker** **Mother: Government worker** **17Y10M** **Male** **TV/book/newspaper/holiday**	Yes, when lava temperature rise up.	Lava rush out of Earth crust and form as a Mountain.	Smoke and lava flow.	I don't know.	Before: There might be some earthquakes. During: smoke come out first, then lava flow, and when lava flow get cold, it become rocks. After: The volcano keep smoking.	I don't know about it.	I don't know.	Somewhere around Pacific Ocean, Mexico, Atlantic Ocean, Taiwan and Philippines.	No.	No, because it never happen to me.	I am not clear about this, but it is better if I can release it is going to erupt as soon as possible.
Student 02 **Father: bank worker** **Mother: Nurse** **18Y04M** **Male** **TV/book/holiday**	Yes, there will be smoke and strong smell.	The place where rocks melt as lava and also the place where lava might erupt.	There are lava, gas, stone. Lava in fact is kind of melting rocks.	I don't know.	Before: Volcanic ash and earthquakes happen. During: Lava, gas and stone come out. After:I don't know	Lava got too many pressure.	I don't know, but not quite often to happen.	Chile and Philippines.	No.	I am a little bit afraid of volcanic eruption, because it has strong destructive power.	Before: People should be announced how to evacuate. After: Try to remedy the damage as good as possible.
Student 03 **Father: unknown** **Mother: Part time worker** **18Y02M** **Male** **Book/newspaper/magazine/computer**	Yes, trees and rocks nearby the volcano mouth start to melt.	Volcano is a special mountain can release geological energy.	Black smoke, stone, volcanic ash and lava.	I don't know.	Before: Maybe there are some earthquakes. During: Black smoke. After: Volcanic ash cover all the things.	Plate tectonics.	Every 1-2 years.	Hawaii and Japan.	No.	No, I am not, because I have never experienced it.	Before: People have to be trained to have quick reaction, and plan the escape line. Police and Fire brigade should be well prepared. After: Rescue and remedy the damage as soon as possible.

Student 04 **Father and mother: Service trades** **17Y10M** **Male** **TV/book/newspaper/computer**	Yes, by observing if temperature rise up.	Lava receive huge pressure and try to release it.	Lava get out from Earth, and smoke as well. It cause huge damage.	I don't know.	Before: Shaking and smoking. During: Lava come out, ash and mushroom cloud. After:: There are a lot of damage on the ground, because of heat, and there is no life, either.	I don't know.	I don't know.	South Pacific Ocean, Italy, and South America.	No.	Yes, I am although I have no experience about it.	Before: We should store water and prepared-food. After: Try to save other people.
Student 05 **Father: Manufacturing industry** **Mother: Housewife** **18Y04M** **Male** **TV/ Magazine**	Yes, by monitoring the change of energy.	Lava store up too many energy and explore from weaker or thinner crust.	There are ash and lava basically. People are also mussy.	I don't know.	Before: people should feel heat. During: Here comes a lot of lava. After: Most place are covered with black stuff (cold lava).	Because the volcano accumulate too much energy.	I am not sure.	Java Sea, and Columbua	No.	Yes, I am. I am afraid of lava and ash mostly, because I could be covered by them.	Before: We should prepare mask and any transports. After: Try to tidy up and rearrange the Disaster area.
Student 06 **Father: Manufacturing industry.** **Mother: Secondary teacher.** **18Y04M** **Male** **TV/book/ Newspaper/ magazine computer**	Yes, the crust nearby the volcano will have movement just before it erupts.	A big movement of Earth crust, and the movement push lava out of the crust.	Lava comes out with smoke, steam, ash and heat.	About 1 hour.	Before: mild earthquakes and temperature rise up. During: earthquakes occur, temperature rise up and smoke. After: There are a lot of damage, it is difficult to recover in a short term.	Crust movement.	Presumably once a year.	Taiwan, Japan and Hawaii.	Yes, but it is a muddy volcano. It is in Yen-Chao, Hua-Lien county.	Yes, Iam. Because I may lose my life and belongings, and it may cause earthquake as well, this is a huge damage.	Before: we must notice if there is any omen. After: Try to join or help the rescue team.
Student 07 **Father and mother: Manufacturing industry.** **18Y01M** **Male** **TV/Film/ Video/ book/ Comic/ Newspaper/ Magazine computer**	Yes, lava will become hotter.	Something are about lava and layer movement	Lava comes out from Earth core with ash and gas.	I don't know.	Before: Shaking. During: lava comes out. After: we should hide in somewhere safe.	I don't know.	1-2 times per year.	Italy	No.	I don't know because I have never experienced it.	Before: Pack up the luggage and leave, at least 10 Km away. After: See what is the damage status and then to decide if we can come back.

Student 08 **Father: police officer** **Mother: Housewife** **18Y08M** **Male** **TV/Film/ Video/ book/ Comic/ Newspaper/ Magazine/ Computer**	Yes, but only in 1 hour, the ash will come out as smoke before it erupts.	Lava come out of from Earth and Earth crust rises up as a hill.	Ash comes up firstly, then lava and finally is gas.	About few hours.	Before: Some ash comes up. During: Lava flow. After: Many things are covered by ash and lava.	Plate tectonics and crust rub against each other cause lava to spit out of Earth.	2-3 times per year.	Far East and Atlantic Ocean.	No.	Yes, I am afraid of heat.	Before: Try to avoid living around the volcanoes. Each family should prepare first-aid kit. After: When it is finish, reopen the disaster area.
Student 09 **Father: Technician** **Mother: Sales** **18Y06M** **Male** **Film/ Comic**	Yes, by detecting the change of energy.	A kind of Earth internal activity.	Lava, mud, ash, and steam.	I don't know.	I don't know.	Volcanoes accumulate too much energy.	5 times for every year.	South Pacific Ocean.	No.	Yes, I am afraid, because I may die of it.	Before: run away from the area. After: Try to re-build the area.
Student 10 **Father: business man** **Mother: Government worker** **17Y09M** **Male** **Book/ Newspaper**	Yes, but just 2-3 hours in advance, basically there are two ways to detect it, firstly, when the frequency of earthquake become higher, it might erupt, secondly, when atmosphere composition contain high sulfur, it might erupt as well.	A passageway for lava to go through from Earth core to the crust, volcanoes look like all the same.	Very thick smoke.	About half day.	Before: Smoke During: Lava flow. After: Cold lava become rocks.	Plates push each other.	Once per year.	Middle America and Far East.	No.	Yes, I am afraid. Because my life and belongings will disappear in a second.	Before: Get away from the area. During: keep away as far as possible. After: Wait for the scientist, don't come any closer.

Student 11 **Father: Driver** **Mother: International Trade company** **18Y04M** **Female** **TV/ Film book**	Yes, by periodicity.	Mountains are with a ridge and somewhere is able to erupt lava.	Smoke and lava come out.	1-2 days	Before: Plate movement and smoke every where. During: Lava comes out. After: Lava becomes solid rocks.	Mid-ocean ridge release energy.	5-10 times per year.	Far East.	No.	Yes, I am afraid, because when it happen, I think I will lack for time to run away.	Before: People should move out to other place. During: It is time to run away. After: I don't know. It really depends on different situation
Student 12 **Father: Businessman** **Mother: Primary teacher** **19Y03M** **Male** **Film/ Video/ Book/ Comic/ newspaper/ Magazine/ computer**	No.	A particular place where contains layer, heat convection and plate tectonic these sorts of Earth movements.	Ash, lava and mushroom cloud.	It is hard to say.	Before: The acidity of underground water will turn to less than Ph-7. During: Shaking heavily. After: When lava cool down , here comes a new Earth surface. Heat convection.	Heat convection.	10 times per year.	Mid-ocean ridge all over the world.	No.	No.	Before: Prepare first aid kit, food and water. After: No ideas.
Student 13 **Father: Government worker** **Mother: Housewife** **18Y07M** **Male** **TV/ Film/ Book/ newspaper**	Yes, by smoking detection.	The place where lava come out, and usually there is a hot spring nearby.	Mushroom cloud, Volcanic bomb, and ash	1 week.	Before: Stop smoking. During: Lava comes out. After: Lava burns down everything.	Crust movement.	1 per year.	Far East, New Zeland, Iceland, and Hawaii.	No.	Yes, I m afraid of heat.	Before: To evacuate all the people. After: To re-build the area.

Student 14 **Father: Cleaning company** **Mother: Businesswoman** **18Y01M** **Male** **TV/ Book/ Newspaper/ Magazine/ Computer**	Yes, but only for old volcano, we can detect eruption by periodicity. For young volcano, we can do nothing.	Volcano is usually where plate does beneath, because Earth core is so hot, the heat brings up high pressure, and the pressure push lava out of the crust, finally create a volcano.	Lava flow, smoking cause gray sky, And ground shaking.	It depends, but normally it takes few days.	Before: I don't know. During: Lava flow. After: Lava get cold and turns to rocks. Everything is covered by ash.	Lava gets high pressure, therefore, it injects from volcano.	1 for 5-6 years.	Philippines and mid-America.	No.	Yes, I am afraid if I am nearby a volcano. But if I am watching volcanic eruption from TV, I am not really scare.	Before: If this is a old volcano, there should be no resident allowed to live here. If it is a new volcano, evacuate al the people. After: I am not sure.
Student 15 **Father: Police officer** **Mother: Housewife** **18Y07M** **Male** **TV/ Film/ Video/ Book/ Newspaper/ Magazine/ computer**	Yes, by detecting internal movements.	A mountain can erupts lava.	Lava flow, and many people should be covered by lava.	Few hours, I think.	Before: Gray sky and black cloud. During: There is high heat comes up. After: Village and city disappear.	Plate tectonic.	1 for every 2 years.	East Africa, mid-America.	No.	Yes, I am, but if it happen, I will escape by taking a airplane.	Before: Evacuate. After: Re-build the area.
Student 16 **Father and mother: Golf Assistant** **17Y08M** **Male** **TV/Film/ Book/ Newspaper/ computer**	Yes, for old volcano we can detect eruption regularly, but only for old volcano.	Lava contain too many energy and spit out of Earth core, and this kind of location is called volcano.	Lava flow and ash.	From half day to one day.	Before: I am not sure. During: Lava flow and ash. After: Cold lava and new layer.	Energy, lava got together, and then erupt.	1 for every 6-7 years.	Taiwan, Australia, Canada and Brazil.	No.	If I experience it by myself, of course, I will be afraid of it. I may lost my life. If I only experience by TV, I won't be afraid of it. Because I know I got safe distance.	Before: Evacuate all the people. After: When lava get colder, we should try to re-build the area.

Student 17 **Father and mother: Business man** **18Y05M** **Male** **TV/film/ Book/ Newspaper**	Yes, by calculating its eruptive periodicity.	The mountains which contain lava inside.	Ash and lava flow	2-3 days	Before: I don't know. During: Lava flow. After: Lava become stone.	Crust movement	1 for 15 years.	Far East, middle East and South America.	No.	Yes, I am afraid of it, because of high heat and poor air quality.	Before: Government should evacuate all the people. After: Try to rebuild the area.
Student 18 **Father: Bank staff** **Mother: Warehouse assistant.** **18Y06M** **Male** **TV/film/ Book/ Newspaper/ magazine**	Yes, by analyzing internal pressure, composition and ground shaking.	Volcano is one of the products of orogenesis and plate tectonic.	Ash and ground shaking are everywhere. Animals are running away.	From few months to a year.	Before: There are ground shaking and animals' extraordinary reactions. During: Lava flow and ash are everywhere. After: I don't know.	Plate tectonic.	1 for every 30-50 years.	Taiwan, Japan, East Africa and East Atlantic Ocean.	No.	Yes, I am, because this is a kind of global disaster.	Before: I will prepare first aid kit, food and water. After: Escape from the disaster area and observe the area for 1-2 years, then see if it is safe to move back.
Student 19 **Father: Pathology technician** **Mother: Medical Cosmetologist** **17Y10M** **Male** **TV/film/ Video/ Book/ Comic/ Newspaper/ Magazine Computer**	Yes, animals have different reaction than usual, and we also can detect eruption by monitoring the change of different chemical concentration and temperature.	The mountains might erupt lava.	Lava and steam.	I am not sure.	I don't know.	Earth crust accumulate thermal energy by friction, and finally release the energy.	I don't know.	Pacific Ocean and Indian Ocean.	No.	Yes, I am. Because I may lost my life or get hurt.	Before: Scientist should calculate the range of disaster, and not allow any activities there. After: Evacuate all the personnel.

Student 20 **Father: Insurance agent** **Mother: Public servant** **18Y05M** **Male** **TV/film/ Video/ Book/ Comic/ Newspaper/ Magazine/Computer**	Yes, by detecting ground shake and gas.	Earth accumulate energy and erupt from thin crust.	Lava flow and lava splash.	Half year.	Before: We can sometimes hear the ground sound. And poisonous increase. During: Gas, ash and lava are everywhere. After: Forest fire, ground temperature decrease.	Lava contain high pressure and erupts from hot spot.	1 for every 100-200 tears.	Taiwan and Hawaii.	No.	Yes, I am afraid, because it has strong power and huge affection.	Before: Scientist can probe the internal structure of volcano and evacuate all the people. After: Make sure everything is safe and repair the all buildings.
Student 21 **Father: Service trade** **Mother: Nurse** **17Y11M** **Male** **TV/film/ Video/ Book/ Comic/ Newspaper/ Magazine/Computer**	Yes, when it is going to erupt, the internal energy will rise up.	Mountains would erupt lava, and this is one of the way that Earth release its energy.	Ash, steam, lava and earthquake.	1-2 minutes.	Before: A big sound. During: Earthquake, lava and ash all over the place. After: I will run away at least 5 Km.	Lava , which comes from Earth core, erupts out of crust, this is caused by overload energy.	1 for every 3 years.	Japan and Madagascar.	No.	Yes, I am afraid of lava and ash, because they can cover my view, make my in danger.	Before: People should learn the relevant knowledge as much as possible. After: Observe the eruptive cycle.
Student 22 **Father: Worker** **Mother: Housewife** **18Y05M** **Male** **TV/film/ Video/ Book/ Comic/ Newspaper/ Magazinecomputer**	Yes, energy form will be changed, firstly, all the energy will become thermal energy, and then become kinetics.	The place where Earth release energy and internal pressure.	Lava flow and smoke.	About half hour.	Before: Shaking. During: Lava flow. After: Lava becomes rocks.	Earth internal pressure is too strong, and erupts from weak point.	4 times per year.	Mid-America.	No.	No, I am not afraid of it, because I have never experienced it.	Before: Evacuate people and avoid taking a bath in hot spring. After: We can use the volcanic rocks as construction material.

Student 23 **Father and mother: Businessman** **18Y02M** **Male** **TV/film/ Book/ Newspaper/ Magazine/Co mputer**	No.	The place where lava come out from undergro und.	Ash , lava, and earthquake s.	It takes few hours.	Before: Earthquakes. During: Lava flow. After: Volcanic ash.	I don't know.	I don't know.	Italy.	No.	Yes, I am afraid of lava , because it is so hot.	Before: People should be banned to live near by volcanic mouth. After: I am not sure yet.
Student 24 **Father and mother: Businessman** **17Y09M** **Male** **TV/ Book/ Newspaper/ Magazine**	No.	Volcano is where crust spilt off, and also lava come out.	Volcanic ash, lava.	It all depends.	Before: I don't know. During: Explosion sound, lava and volcanic ash. After: Volcanic ash all over the place.	I am not sure.	1 per year.	I have no ideas.	No.	No, I am not afraid of it, because I have never experienced it.	No ideas.
Student 25 **father and mother : businessman** **18Y05M** **Male** **TV/film/ Video/ Book/ Comic/ Newspaper/ Magazine/Co mputer**	Yes, basically water quality will become sour taste and all the animals are running away.	Volcano is where lava show up.	Volcanic ash, lava and stone are everywhere .	It takes few days.	Before: The water acidity will below Ph 7. and animals will leave the place. During: There are a lot of volcanic ash. After: Volcanic ash and cold lava all over the place.	The internal pressure of the volcano is too strong.	1 for every 3i5 years.	Esat Africa, Itlay, mid-America, Canada and South America.	No.	Yes, I am afraid of it, because I may lose my life.	Before: Evacuate all people. During: Move to the high land. After: I don't know.

Appendix 5: The Understanding of Earthquakes in Primary School Year 3

	0. Are earthquakes predictable?	1. What is an earthquake?	2. What happens during an earthquake?	3. How long does an earthquake last?	4. What does it look like before/during/after an earthquake?	5. What causes an earthquake to happen?	6. How often do earthquakes happen?	7. Where do earthquakes occur?	8. Have you ever experienced an earthquake in any other country/place?	9. Are you afraid of earthquakes?	10. What should we/you do before/during/after an earthquake?
Student 01 **Father: Technician** **Mother: Housewife** **12Y08M** **Male** **TV/film/ Video/ Book/ newspaper**	Yes, but don't know how to do it.	Everything shakes.	Things are shaking and falling down.	Few minutes.	Before: No ideas. During: Everything is shaking. After: Things fall down all over the floor.	No ideas.	Insensible earthquakes: Every few month. Sensible earthquakes: Every few year.	Taiwan, Japan, China and South Asia.	Taiwan only.	No, because it finish only in few minutes.	Before: Fix everything properly. During: Hide under a strong object. After: Tidy up everything.
Student 02 **Father: Public servant.** **Mother: Housewife** **12Y08M** **Male** **TV/film/ Video/ Book/ Newspaper/ Magazine/ Computer**	No.	Ground shaking.	Doors and windows make noise because they all shake heavily. Lamps are shaking as well.	About 1 minute.	Before: Small shaking. During: Strong shaking. After: I feel dizzy.	Two or more trenches hit each other.	No ideas.	Whole world.	Taiwan only.	Houses fall down, mud flow attacks cities, doors and windows can not be opened, people are trapped inside the houses.	Before: Open the door and keep exits clear. After: Stay near by the refrigerator, because I can rely on the foods inside.
Student 03 **Father: Driver** **Mother: Housewife** **12Y08M** **Male** **TV/ Video/ Book/ Newspaper/ Magazine computer**	No.	A kind of hazard, houses fall down by heavily shaking.	Lamps shaking and I feel dizzy.	It all depends, but about in 5 minutes.	Before: No ideas. During: No ideas. After: Houses fall down.	No ideas.	Once a month.	Taiwan, China, Australia and USA.	Taiwan only.	Yes, because houses fall down and people might lose their life.	Before: Switch off gas and open the door. After: Replace everything damaged.

Student 04 **Father and mother: Technician** **12Y08M Female** **TV/film/ Video/ Book/comic/ Newspaper/ Computer**	No.	Ground shaking.	Houses fall down or tilt, sometime s split.	About 5 minutes.	Before: No ideas. During: Shaking. After: Many houses broken up.	No ideas.	No ideas.	Taiwan.	Taiwan only.	**I am afraid of strong earthquakes , because I will be hit by things which fall down from high place. But I am not afraid of mild earthquakes .**	Before: Prepare torch. And switch off all the power. During: Stay under the tables. After: Move to the other house.
Student 05 **Father: Business. Mother: Lawyer** **12Y08M Male** **TV/ Book/ Newspaper/ Magazine/ computer**	Yes, it is possible.	No ideas.	I feel horrible, because things fall down.	In 5 minutes.	Before: No ideas. During: No ideas. After: Watch the news.	No ideas.	No ideas.	Taiwan, China and middle East.	Taiwan only.	**Yes, no particular reason, just feel horrible.**	No ideas.
Student 06 **Father: Chef Mother: Nurse** **12Y07M Male** **TV/ Video/ Book/ Newspaper/ computer**	Yes, I think we can use satellite to detect the earthquak es.	It is a kind of hazard.	Houses fall down.	About in 10 minutes.	Before: No ideas. During: Things are shaking. After: People might die.	No ideas.	Once a year.	Taiwan and USA.	Taiwan only.	**Yes, a little, I am afraid I will be flattened by any object.**	Before: No ideas. During: No ideas. After: Escape from the area.
Student 07 **Father: Sales Mother: Housewife** **13Y07M Male** **TV/film/ book/ newspaper computer**	Yes, if the sky is getting red, it is going to have an earthquak e.	Plate tectonic.	Floor split and power failure. People are screaming .	About in half hour.	Before: Things are shaking. During: Things are shaking heavily and falling down. After: Everything calm.	Plate tectonic.	Once every 2 years.	Taiwan, Japan, Philippin es, India and South America.	Taiwan only.	**Yes, I am afraid of shaking.**	Before: Prepare torch. During: Tidy up the area.

Student 08 **Father and Mother: Unknown jobs** **12Y04M Male** **TV/film/ Video/ Book/comic/ magazine**	No, I don't think so.	No ideas.	No ideas.	No ideas.	Before: No ideas During: Things are shaking. After: No ideas.	No ideas.	Once a year.	Taiwan.	No ideas.	Yes, I feel shaking is horrible.	No ideas.
Student 09 **Father: Engineer Mother: Housewife** **12Y04M Male** **TV/film/ Video/ Book/ Comic/ magazine newspaper computer**	No.	Ground shaking.	Lamps are shaking.	It takes few minutes.	Before: No feeling at all. During: Everything is shaking. After: No shaking at all.	Plate tectonic.	I don't know.	Everywhere in the world.	Taiwan only.	No, because I don't think it is a serious problem to me.	Before: Do not put china and glass in the high places. After: Tidy up everything.
Student 10 **Father: Security Guard Mother: Pass away.** **12Y01M Male** **TV/film/ Video**	No.	Ground shaking.	Cabinet will open because of heavy shacking.	In 5 minutes.	Before: Feel nothing different. During: Shaking heavily. After: Feel horrible.	Volcanic eruptions.	Any time.	Japan and USA.	Taiwan only.	I am afraid of strong earthquakes because shaking is so heavy. I am not afraid of mild earthquakes.	Before: No ideas. After: move to an open place.
Student 11 **Father: Designer Mother: Bank staff.** **13Y 01M Male** **TV/film/ Video/ magazine newspaper Computer**	No.	No ideas.	Things are shaking and falling.	Few hours.	Before: No ideas During: Shaking. After: No ideas.	No ideas.	1-2 years.	Korea, Taiwan, Australia and center America.	Taiwan only.	Yes, I am afraid of it, but I am not sure the reason.	No ideas.

Student 12 **Father: Self-employer** **Mother: Housewife.** **13Y00M** **Female** **TV/book/ Comic**	Yes, the deep water fish would swim to the shallow water.	No ideas.	Ground shaking.	Few seconds.	Before: the deep water fish would swim to the shallow water. During: Houses fall down. After: Almost everything collapses.	No ideas.	Few months.	Taiwan , New zealand, Mongolia and South America.	Taiwan only.	Yes, because I might be hit by any object.	Before: Open the windows and doors. After: Tidy up the area.
Student 13 **Father: Self-employer** **Mother: Housewife** **12Y11M** **Male** **TV/film/book? Newspaper/ computer**	No.	No ideas.	Things are shaking.	About 5 seconds.	Before: I don't know. During: Things are falling down. After: Everything stop shaking.	No ideas.	No ideas.	Taiwan and China.	Taiwan only.	I am a little afraid of it, because things fall down.	Before: No ideas. After: Replace everything damaged.
Student 14 **Father and mother: Beauty shop owner.** **13Y09M** **Female** **TV/book/ Magazine/ computer**	No.	Ground shaking.	Many things are shaking and falling down.	1 minute.	Before: No. During: Ground shaking and things fall down. After: Stop shaking.	No ideas.	No ideas.	No ideas.	Taiwan only.	Yes, because many objects could hit my head.	Before: No ideas. After: Carry on any unfinished business.
Student 15 **Father: Public servant** **Mother: Unknown job** **12Y10M** **Male** **TV/film/ Book/ newspaper computer**	No.	Ground shaking.	I feel horrible and many things are moving to everywhere.	2-3 minutes.	Before: No ideas. During: A lot shaking. After: People are still afraid of it.	Layers are crushed by Earth stress.	Every 10 years.	Taiwan, India and middle East.	Taiwan only.	Yes, but just a bit, mostly I am afraid of house collapse.	Before: I don't know.. After: Rebuild the houses.

Student 16 **Father:** **Taxi driver** **Mother:** **Technician** **13Y05M** **Female** **TV/film** **Video/** **Book/** **Comic/** **Newspaper/** **Magazine/** **computer**	Yes.	For mild one: Things are shaking. For strong one: Many things are falling down.	Many people try to stay under tables.	I don't know.	Before: I don't know. During: Shaking. After: Things are in great confusion.	No ideas.	Once a year.	New Zealand, Taiwan and Japan.	Taiwan only.	Yes, I am afraid of things falling down.	Before: Fix everything. After: Tidy up the houses and environment.
Student 17 **Father:** **A staff in radio company.** **Mother:** **Primary school teacher.** **12Y09M** **Male** **TV/film** **Video/** **Book/** **Newspaper/** **Magazine** **Computer**	No.	No ideas.	No ideas.	No ideas.	No ideas.	No ideas.	No ideas.	Taiwan.	Taiwan only.	Yes, because it shakes.	No ideas.
Student 18 **Father and mother:** **Businessman** **12Y05M** **Female** **TV/film** **Video/** **Book/** **Newspaper/** **Magazine/** **Computer**	Yes.	Houses are shaking.	Lamps are shaking.	In 10 minutes.	Before: I don't know. During: Shaking. After: Everything is calm.	No ideas.	No ideas.	Taiwan and Japan.	Taiwan only.	Yes, a little, because things are falling down.	No ideas.

Student 19 **Father: Designer.** **Mother: Housewife.** **12Y05M** **Female** **TV/film** **Video/** **Book/** **Newspaper/** **Magazine/** **computer**	No.	Ground shaking.	Things are falling down.	1 minute.	Before: No ideas. During: Shaking. After: Walls broken.	No ideas.	It all depends. But on the 11/09 of every year, it may have strong earthquak e.	Taiwan and Japan.	Taiwan only.	No, because I feel funny.	Before: No ideas. After: Tidy up the area and repair the walls.
Student 20 **Father: Self-employer** **Mother: Housewife.** **12Y04M** **Female** **TV/film** **Video/** **Book/** **Newspaper/** **computer**	No.	Earth shaking and things are falling down.	Things are falling down.	No ideas.	Before: Mild shaking. During: Things are falling down. After: No ideas.	No ideas.	No ideas.	Earthqua kes.	No ideas.	Yes, because if heavy thing falls down, I might be flatten to death.	No ideas.
Student 21 **Father And Mother: Businessman** **13Y01M** **Female** **TV/film** **Video/** **Book/** **Newspaper/** **Magazine** **computer**	Yes, by detecting shaking.	Ground shaking.	Things are falling down and ground is shaking.	Half hour.	Before: No ideas. During: Shaking. After: Houses are in great confusion.	No ideas.	No ideas.	Japan, Taiwan, China, Australia and USA.	Taiwan only.	Yes, things are falling down and hits people.	Before: Fix everything. After: No ideas.
Student 22 **Father: No job.** **Mother: Bakery staff.** **12Y03M** **Male** **TV/film/** **Book** **Newspaper** **Computer**	No ideas.	Everythin g shakes at the same time.	Ground is shaking and things are falling down on the floor.	Few seconds.	Before: No ideas. During: Shaking. After: No ideas.	No ideas.	No ideas.	Taiwan.	Taiwan only.	Yes, because roof might collapse.	Before: No ideas. After: Tidy up ever thing.

Student 23 Father: No job Mother: Worker. 11Y10M Female Film Video/ Book/ Newspaper/ computer	No.	No ideas.	Things are falling down.	Few minutes.	Before: No ideas. During: Shaking. After: No ideas.	No ideas.	No ideas.	Taiwan and Japan.	Taiwan only.	Yes, houses fall down and flatten many people.	Before: No ideas. After: Rebuild the area.
Student 24 Father: Service trade Mother: Housewife 12Y07M Female TV/book/ Newspaper	No.	Houses are shaking and every falls down.	Things are falling down from the high places.	2-3 minutes.	Before: Nothing happen. During: Shaking. After: Many things fall down all over the place.	No ideas.	No ideas.	Taiwan and China.	Taiwan only.	Yes, because things may fall down and hit me.	No ideas.
Student 25 father and mother: businessman 12Y11M Female TV/film Video/ Book/ Comic/ Newspaper/ Magazine/ computer	No.	No ideas.	Houses are falling down.	Few minutes.	Before: Mild shaking. During: Strong shaking. After: No ideas.	No ideas.	No ideas.	Taiwan.	Taiwan only.	Yes, but it is hard to tell why.	No ideas.

Appendix 6: The Understanding of Earthquakes in Primary School Year 6

	0. Are earthquakes predictable?	1. What is an earthquake?	2. What happens during an earthquake?	3. How long does an earthquake last?	4. What does it look like before/during/after an earthquake?	5. What causes an earthquake to happen?	6. How often do earthquakes happen?	7. Where do earthquakes occur?	8. Have you ever experienced an earthquake in any other country/place?	9. Are you afraid of earthquakes?	10. What should we/you do before/during/after an earthquake?
Student 01 **Father: Technician** **Mother: Housewife** **12Y08M** **Male** **TV/film/ Video/ Book/ newspaper**	Yes, the animals will move to somewhere, for example: animals in the mountains will leave the mountains, ants will run out of ground few days before it happen.	Ground shaking and left many deaths.	Lamp Shaking, things falling and I feel every thing shaking.	About few seconds.	Before: There should be some omens, but I don't know what it is. During: Everything shakes heavily. After: Here comes small earthquakes in few weeks time.	Plate tectonic, two plates push to each other.	It is hard to say.	Japan, Taiwan and China.	Taiwan only.	Yes, because things fall down and they might hit me.	Before: Take off anything which are breakable from high place. No thing is allowed to put in front of the exit. During: Open the window and door in the first time. After: Call the police.
Student 02 **Father: Public servant.** **Mother: Housewife** **12Y08M** **Male** **TV/film/ Video/ Book/ Newspaper/ Magazine/ Computer**	No.	Plates push to each other and cause ground shaking.	Shaking.	In about 30 seconds.	Before: Mild shaking. During: Main shaking. After: Shaking stop.	Plates push to each other.	No ideas.	Taiwan, Japan, China, South Asia and Middle East.	Taiwan only.	No, because I can do nothing to stop it, so fear is not necessary.	Before: Switch off all the power. During: Move to the corner of the building or near by a pillar, in the outdoor, stay in an open place. After: Check the damage and re-build the area.

Student 03 **Father: Driver** **Mother: Housewife** **12Y08M** **Male** **TV/ Video/ Book/ Newspaper/ Magazine Computer**	No.	Plates push to each other and cause ground shaking.	The flower vase falls on the floor and lamps are shaking.	Few minutes only.	Before: Ground Wave slowly. During: Main shaking. After: I can see the broken vase.	Plates movements.	No. ideas.	Taiwan, Japan, USA, Canada, South America, Middle East and Indonesia.	Taiwan only.	Yes, because houses broken down.	Before: Fix everything well. During: Hide under a table, if in the outdoor, stay in a open place. After: Check everybody and everything.
Student 04 **Father and mother: Technician** **12Y08M** **Female** **TV/film/ Video/ Book/comic/ Newspaper/ Computer**	No.	Earth crusts hit each other and cause ground shaking.	Things shaking and ground shaking as well.	I am not sure.	Before: Mild shakes. During: Strong shakes. After: Shaking stop.	Earth crusts hit each other.	For main earthquakes: I don't know. For mild earthquakes: Always happen.	Taiwan and Japan.	Taiwan only.	No, because I know how to deal with it.	Before: Switch off the gas. During: Stay under a table or nearby the pillar. If I am in the outdoor, I will find an open place. After: Call the police.
Student 05 **Father: Business.** **Mother: Lawyer** **12Y08M** **Male** **TV/ Book/ Newspaper/ Magazine/ Computer**	Yes, the earthworm would come out of ground few days before earthquakes.	It is a big shaking and many people lose lives.	House collapse and stones fall down.	Few minutes.	Before: It looks calm. During: Many buildings collapse. After: People try to rescue other people who are in the danger.	I don't know.	I don't know.	Taiwan, Japan and Korea.	Taiwan only.	Yes, because houses always fall down.	Before: Do not put potted flower in the balcony. During: Stay under a table or open place. After: Try to help other people.

Student 06 **Father: Chef** **Mother: Nurse** **12Y07M** **Male** **TV/ Video/ Book/ Newspaper/ Computer**	Yes, because some animals have unusual reaction, for example, earthworm would come out of the ground few hours before the earthquakes.	Plates rub against to each other, and cause ground shaking.	Window smash, house falling down and everything falls down as well.	Few minutes only.	I don't know.	**Plates rub against to each other.**	**Once for few years.**	**Taiwan, China and East Europe.**	**Taiwan only.**	**No, because I am used deal with it.**	Before: Prepare water and food. During: Run to an open place or nearby a pillar. After: I don't know
Student 07 **Father: Sales** **Mother: Housewife** **13Y07M** **Male** **TV/film/ book/ newspaper computer**	Yes, but I don't know by how.	Some sorts of wave come from underground.	Water and lamp shakes heavily.	Between 10-20 minutes.	Before: Slow wave. During: Strong wave. After: Wave stop.	Earth crust and plates hit to each other.	I don't know.	Taiwan, Japan, Korea and China.	Taiwan only.	**No, because this has already become a part of my life.**	Before: Prepare food and water. During: Stay under a table and a tree. After: Help some body in danger.
Student 08 **Father and Mother: Unknown jobs** **12Y04M** **Male** **TV/film/ Video/ Book/comic/ Magazine**	Yes, some fish will jump out of water.	Plates hit each other.	Lamp and water are shaking. Cabinet falls down.	It all depends.	Before: I don't know. During: Shaking. After: I don't know.	Plates strike each other.	It all depends.	Taiwan.	Taiwan only.	No.	Before: Put important documents and money in a safe place. Prepare food and water. During: Open window and door in the first time. Go to a flat place After: Try to re-build the area.

.											
Student 09 **Father: Engineer** **Mother: Housewife** **12Y04M** **Male** **TV/film/ Video/ Book/ Comic/ magazine newspaper computer**	No.	The shaking of Earth surface.	Table, chair and lamp are waving.	Few seconds.	Before: Every thing is calm. During: Terrible shaking. After: Discussing how to solve the damage with family.	The shaking of Earth crust.	It all depends.	Taiwan, Japan, China and USA.	Taiwan only.	Yes, because lamp and whole house might fall down.	Before: Fix everything. During: Stay in an open place or nearby a table. After: Re-fix something wabbling.
Student 10 **Father: Security Guard** **Mother: Pass away.** **12Y01M** **Male** **TV/film/ Video**	Yes, but I don't know by what way.	Plates rub against to each other and cause shaking.	Mud flow, house falling and so many people complain about the losing.	Few minutes.	Before: Everything is calm. During: People become panic. After: People start to complain because they lose everything.	Plate movement .	It all depends.	Taiwan, China and north Africa.	Taiwan only.	No, because I feel nothing serious.	Before: Do not over open up the land. During: Stay under the table or huge object. After: Repair the house.
Student 11 **Father: Designer** **Mother: Bank staff.** **13Y 01M** **Male** **TV/film/ Video/ magazine newspaper Computer**	No.	Lava flow from the Earth center have a big movemen t and cause the shaking.	Walls are leaking and things fall down.	Few seconds.	No ideas.	No ideas.	Few years.	Taiwan, Japan, China and Middle East.	Taiwan only.	No, because I have never seen something really bad.	Before: Prepare a iron table and life ladder. During: Use life ladder to escape or stay under a table. After: Re-build the area.
Student 12 **Father: Self-employer** **Mother: Housewife.** **13Y00M** **Female**	Yes, because some insects will escape few days ago before earthqua kes.	Ground Shaking.	Things fall down and people running away. Also cars stop on the road.	Few seconds to few minutes.	Before: Nothing happen. During: Everything is shaking. After: A lot of damage.	Earth release the energy.	No ideas.	Taiwan.	Taiwan only.	I feel ok, not so afraid of it, because it just a while.	Before: Fix everything. During: Go to an open area. After: Contact with family and friends to check if they

TV/book/ Comic											are all right.
Student 13 **Father: Self-employer Mother: Housewife** **12Y11M Male** **TV/film/book ? Newspaper/ Computer**	Yes, but I don't know the way.	The change of Earth crust and cause shaking.	The shop sign fall down, people are panic.	In 5 minutes.	Before: Mild wave up and down direction. During: Left and right direction shaking. After: From Left and right direction shaking to stop shaking.	The movements of Earth crust.	I don't know.	Taiwan.	Taiwan only.	I feel ok, not very afraid of it. Because there is none of my family get harm from them.	Before: Open the window. During: Stay under a table. After: Tidy up everything.
Student 14 **Father and mother: Beauty shop owner.** **13Y09M Female** **TV/book/ Magazine/ Computer**	Yes, because we can see something change in the surface of Earth crust.	Plates hit each other and get shaking.	Many people are dead, and many houses are falling down.	I am not sure.	Before: It shakes lightly. During: Strong shake. After: Some other mild earthquakes come after.	Plate tectonic.	For main earthquakes: Every half to one year. For mild earthquake: Every day.	Taiwan, Japan, USA and North Pole.	Taiwan only.	No, because it is just some shaking, It is fun to me.	Before: Prepare food. During: It is better to stand between 2 doors or stay in an open area. After: To examine the escaping plan.
Student 15 **Father: Public servant Mother: Unknown job** **12Y10M Male** **TV/film/ Book/ newspaper computer**	No.	Plate movement.	Lamps and water are waving.	I am not sure.	Before: No ideas. During: Wave from up and down direction to left and right direction. After: Lots of damages everywhere.	No ideas.	I am not sure.	Taiwan.	Taiwan only.	For mild earthquakes : no. For strong earthquakes : Yes, because things might fall down to hit me.	Before: No ideas. During: Stay under table or an open place. After: Make a reaction plan.

Student 16 **Father: Taxi driver** **Mother: Technician** **13Y05M** **Female** **TV/film Video/ Book/ Comic/ Newspaper/ Magazine/ computer**	Yes, by machine detection and animals' unusual reactions.	Plates rug against to each other.	Many people are dead, houses fall down and ambulance are everywhere.	I am not sure.	Before: Animals have unusual reaction. During: Shaking heavily. After: Houses fall down and people are trapped inside.	Plate rugs against to each other.	Mild earthquakes: It happens everyday. Strong earthquakes: Every half to one year.	Far East.	Taiwan only.	No, because I think it is naturally thing, so there is nothing to be afraid of.	Before: Prepare food and torch. During: Stay under a table or anything strong enough. After: Repair the damage.
Student 17 **Father: A staff in radio company.** **Mother: Primary school teacher.** **12Y09M** **Male** **TV/film Video/ Book/ Newspaper/ Magazine Computer**	Yes, tortoise will go north few days before it happen.	Plate movement.	Houses fall down and cars are waving.	20-30 seconds.	Before: Everything is calm. During: Big waving. After: No ideas.	Plate movement.	Strong earthquakes: I am not sure. Mild earthquakes: Always happen.	Far East.	Taiwan only.	No, because it is fun to me.	Before: Prepare food and water. During: Stay under a bed or table. After: Move to an open place.
Student 18 **Father and mother: Businessman** **12Y05M** **Female** **TV/film Video/ Book/ Newspaper/ Magazine/ Computer**	Yes, the crocodiles will become more aggressive. 1-2 days before earthquakes happen.	Plates rug against to each other.	Lamps are waving	1-2 minutes.	Before: Animals have unusual activities. During: Things are shaking regularly, from up and down direction to left or right direction.	Volcanic eruptions or plate tectonic.	Strong earthquakes: I am not sure. Mild earthquakes: Always happen.	Whole word.	Taiwan only.	No, because it is fun to me.	Before: Fix everything. During: Stay at the corner, or between cabinets or beds. After: Check up everything and exercise the reaction plan.

Student 19 **Father: Designer.** **Mother: Housewife.** **12Y05M** **Female** **TV/film** **Video/** **Book/** **Newspaper/** **Magazine/** **computer**	I don't know.	Ground shaking.	Houses are shaking and ground splits open.	Few seconds.	Before: Lamps shake heavily. During: Lamps still shake heavily but stronger. After: Stop shaking.	No ideas.	No ideas.	Whole word.	Taiwan only.	Yes, because I might lose my life.	Before: No ideas. During: Stay under a table and protect the head. Or stay in the corner of the house. After: Re-build the area. Or give some donations.
Student 20 **Father: Self-employer** **Mother: Housewife.** **12Y04M** **Female** **TV/film** **Video/** **Book/** **Newspaper/** **computer**	Yes, by detecting the mild shakes.	Ground shaking.	Trees are falling down and houses might leak.	In half hour.	Before: It shakes slowly. During: It shakes strongly. After: there are some mild earthquakes come after.	Plate rugs against to each other.	No ideas.	Taiwan, China and South America.	Taiwan only.	Yes, because things might fall down and hit me.	Before: take off everything from high places. During: Stay under a table or corner of a house. After: Try to help others.
Student 21 **Father And Mother: Businessman** **13Y01M** **Female** **TV/film** **Video/** **Book/** **Newspaper/** **Magazine** **Computer**	No.	No ideas.	Things fall down and mud flow happen.	Few minutes.	No ideas.	No ideas.	No ideas.	Taiwan	Taiwan only.	I feel ok, because I am used to deal with it.	Before: Do not put anything in high places. During: Stay under a table. After: Try to help others.
Student 22 **Father: No job.** **Mother: Bakery staff.** **12Y03M** **Male** **TV/film/** **Book** **Newspaper** **computer**	Yes, but I don't know by what way.	Ground shaking.	Huge shaking, and things fall down.	About in 2 minutes.	Before: Mild shaking for long time. During: Heavy shaking for a moment. After: Earth crust might split.	Plate hit each other.	No ideas.	Taiwan, Japan and China.	Taiwan only.	No, but I don't know why.	Before: Switch off the gas. During: Put soft staff over the head. After: Tidy up the area.

Student 23 **Father:** **No job** **Mother:** **Worker.** **11Y10M** **Female** **Film** **Video/** **Book/** **Newspaper/** **computer**	No.	The stress press Earth crust and cause the shaking.	Houses are shaking.	Few minutes.	Before: It shakes from up to down direction. During: It shakes from left to right direction. After: Stop shaking.	The stress press Earth crust.	No ideas.	Taiwan and Madagascar.	Taiwan only.	No, I feel it is ok to me.	Before: Put anything breakable in the lower position. During: Stay under a table or go to an open area. After: Check up everything.
Student 24 **Father:** **Service trade** **Mother:** **Housewife** **12Y07M** **Female** **TV/book/** **Newspaper**	No.	Ground shaking.	Shaking.	In 1 minute.	No ideas.	Plate tectonic and all kind of artificial waving.	Mild earthquake: No ideas. Strong earthquake: Every 2-3 years.	Whole word.	Taiwan only.	Yes, if it is strong, because houses might fall down.	Before: Do nothing. During: Open doors and windows. After: Try to help others.
Student 25 **father and mother:** **businessman** **12Y11M** **Female** **TV/film** **Video/** **Book/** **Comic/** **Newspaper/** **Magazine/** **computer**	Yes, but no ideas about how to do so.	No ideas.	Things are falling down, and everything is shaking.	No ideas.	Before: Mild shakes. During: It is getting stronger and stronger. After: Several mild earthquakes come after in 1-2 days.	No ideas.	No ideas.	Taiwan	Taiwan only.	Yes, because houses might fall down.	Before: No ideas. During: Stay under any strong object or go to an open area. After: Tidy up everything.

Appendix 7: The understanding of Earthquakes in Junior High School Year 3

	0. Are earthquakes predictable?	1. What is an earthquake?	2. What happens during an earthquake?	3. How long does an earthquake last?	4. What does it look like before/during/after an earthquake?	5. What causes an earthquake to happen?	6. How often do earthquakes happen?	7. Where do earthquakes occur?	8. Have you ever experienced an earthquake in any other country/place?	9. Are you afraid of earthquakes?	10. What should we/you do before/during/after an earthquake?
Student 01 **Father: Technician** **Mother: Housewife** **12Y08M** **Male** **TV/film/ Video/ Book/ Newspaper**	Impossible.	Earth crust rug against to each other.	Water and lamps are waving.	10 seconds.	Before: Nothing happen or may be a weak earthquake. During: Main shaking last about 10 seconds. After: Still some tremors, each one last about 5 seconds.	The movements of shear plate.	I am not sure.	Circum Pacific belt.	Taiwan only.	No, because the epicenter of earthquakes are not usually in the north Taiwan.	Before: To train people how to react earthquakes. After: try to forget the bad feeling and be aware of the next coming earthquakes.
Student 02 **Father: Public servant.** **Mother: Housewife** **12Y08M** **Male** **TV/film/ Video/ Book/ Newspaper/ Magazine/ Computer**	Yes, when the record of detective machine shows there have been no shaking for long time, there may have an earthquake soon.	Plate tectonic.	Things are shaking and falling down, if it is a strong earthquake, then the ground may break.	1-3 minutes.	Before: No feeling. During: Very strong shaking. After: Stop shaking.	Plate tectonic.	Insensible earthquakes: Every day, all the time. Sensible earthquakes: 3-5 times per year.	Circum Pacific belt, South Asia, and Arabian sea.	Taiwan only.	No, I am not really afraid of it, because my family always well prepared for it.	Before: Do not over use and develop the hills. After: Try to tidy up the damage.

Student 03 **Father: Driver** **Mother: Housewife** **12Y08M** **Male** **TV/ Video/ Book/ Newspaper/ Magazine computer**	Yes, I think so.	Plate tectonic.	Animals have extraordinary behavior.	5-15 seconds.	Before: No feeling. During: Shaking. After: People run away from the area.	Plate tectonic and volcanic eruptions.	Insensible earthquakes: Everyday. Sensible earthquakes: 10-20 times per year.	Asia and America.	Taiwan, Japan and USA.	It all depends, if I am in school, I will be afraid of it ,because the buildings in school look very old, I may lose my life.	Before: Do not put potted flower in the high place, and repair any old housing equipment. After: Watch news, get the latest information all the time.
Student 04 **Father and mother: Technician** **12Y08M** **Female** **TV/film/ Video/ Book/comic/ Newspaper/ Computer**	No, human have not that kind of ability yet.	The movements between faults and Earth crust.	Houses collapses and things are falling down.	30 seconds to 1 minute.	Before No thing happen. During: Main shaking. After: A lot of Earth tremors in one week time.	Fault movements.	Insensible earthquakes: All the time. Sensible earthquakes: 20 times per year.	Circum Pacific belt, and India.	Taiwan only.	No, because when it happens, I am not the only one to deal with it.	Before: Prepare water and torch. After: Switch off the gas and power.
Student 05 **Father: Business.** **Mother: Lawyer** **12Y08M** **Male** **TV/ Book/ Newspaper/ Magazine/ Computer**	Yes, we can observe the unusual behavior from animals, such as mouse would like to leave their nest.	The interactions between fault and Earth crust.	The ground could bulge, and mountains may have displacement.	1-2 minute.	Before: Mild shaking. During: Main shaking. After: Tremors come after soon for 2-3 times.	Plate tectonic and areolite.	Insensible earthquakes: All the time. Sensible earthquakes: Less than 5 times per year	Circum Pacific belt and Atlantic belt.	Taiwan only.	No, because it is useless to be afraid of it.	Before: Try to strengthen the AID and escaping training. After: Exercise the reaction plans.

Student 06 **Father: Chef** **Mother: Nurse** **12Y07M** **Male** **TV/ Video/ Book/ Newspaper/ computer**	No, because it always happens in a sudden.	Plate tectonic.	The ground bulge up and houses are falling down, sometimes mud flow happens.	In 1 hour.	Before: No ideas. During: Shaking. After: There are still many Earth tremors come after.	No ideas.	Insensible earthquakes: Many times a day. Sensible earthquakes: 10 times per year.	Far East.	Taiwan only.	I don't really afraid of it, because I feel shaking is a bit funny.	Before: No ideas. After: Try to deal with problems and difficulties properly.
Student 07 **Father: Sales** **Mother: Housewife** **13Y07M** **Male** **TV/film/ book/ newspaper computer**	Yes, we can use machines to detect seismic waves.	Ground is shaking.	Houses are falling down	About 30 seconds.	Before: Ants are running away. During: No ideas. After: Earth tremors come after.	Plate tectonic.	Taiwan, Japan and Korea.	Insensible earthquakes: Any time. Sensible earthquakes: 4-5 times per year.	Taiwan only.	No, because I believe all the things has already been decided to God.	No ideas.
Student 08 **Father and Mother: Unknown jobs** **12Y04M** **Male** **TV/film/ Video/ Book/comic/ Magazine**	Yes, earthworm will be out of the ground and snakes could stay on the road.	Plate tectonic.	Desks are shaking and many people are dead.	5-20 minutes.	Before: Animals have unusual behavior. During: Shaking. After: Earth tremors, come after in 5 minutes.	Some sort of shear stress applies on plates.	Insensible earthquakes: 30-40/year. Sensible earthquakes: 5-6/year.	Taiwan, Japan and USA.	Taiwan only.	No, because I have never experienced a real strong earthquake.	Before: Use good material to build the houses. After: Strengthen building structure when necessary.
Student 09 **Father: Engineer** **Mother: Housewife** **12Y04M** **Male** **TV/film/ Video/ Book/ Comic/ magazine newspaper Computer**	No.	Strata break up and cause ground shaking.	Building gets damage.	1-2 minutes.	Before: Mild shaking. During: Strong shaking. After: There are so many tremors come after.	Plate tectonic and Earth release its energy.	Insensible earthquakes: Many times a day. Sensible earthquakes: 10/year.	Taiwan, Iceland and USA.	Taiwan only.	No, because I am used to live with earthquakes.	Before: Prepare medicine, food and water. After: Re-exercise the reaction plan.

Student 10 **Father: Security Guard** **Mother: Pass away.** **12Y01M** **Male** **TV/film/ Video**	Yes, by detecting seismic waves, and try to find out the regulation.	Plate tectonic.	Things are falling down.	1-2 minutes.	Before: Animals have unusual behavior, ants will leave their nest. During: Things are shaking. After: Many buildings are falling down.	Plate tectonic.	Insensible earthquakes: Many times a day. Sensible earthquakes: 5-10/year.	South-East Asia.	Taiwan only.	I am afraid of strong earthquakes. Because houses may fall down toward me.	Before: Exercise the reaction drill. After: Check up building structure regularly.
Student 11 **Father: Designer** **Mother: Bank staff.** **13Y 01M** **Male** **TV/film/ Video/ magazine newspaper Computer**	Yes.	Plate tectonic and cause ground shaking.	Building falling down and bet fire.	1 minute.	Before: No ideas. During: Things are falling down. After: Many houses collapse.	Plate tectonic.	Insensible earthquakes: Many times a day. Sensible earthquakes: 5-4/year.	Taiwan and China.	Taiwan only.	No, because I think shaking is not so horrible, but if I watch from television, I feel horrible.	Before: Design a strong building with a good structure. After: Try to save other people.
Student 12 **Father: Self-employer** **Mother: Housewife.** **13Y00M** **Female** **TV/book/ Comic**	No.	Ground shaking which is caused by plate converge and diverge.	Everything is shaking and children are carrying.	Few seconds.	Before: There are some unusual animal reaction. During: Shaking. After: Earth tremors come after.	Plate tectonic.	Insensible earthquakes: Many times a day. Sensible earthquakes: Below 50/year.	Taiwan, Japan and Philippines.	No, Taiwan only.	Yes, but I only afraid of strong one, because I may be hit by something.	Before: Buy a good insurance. After: If it is necessary. Change the structure of building.

Student 13 **Father: Self-employer Mother: Housewife** **12Y11M Male** **TV/film/book ? Newspaper/ computer**	Yes, crocodiles will roar loudly 2-3 days before it happen.	Ground shaking.	Many people run away and things are falling down, supermarket get a lot of people.	Few seconds to 5 minutes.	Before: Animals may have extraordinary behavior. During: Ground shaking and sea tide become stronger. After: Try to prevent the same damage happen again.	Plate tectonic.	Insensible earthquakes: Many times a day. Sensible earthquakes: Below 1-2/year.	Taiwan, Japan and North USA.	Taiwan only.	Yes, I am afraid of strong one, because I may lose my life.	Before: No. After: Contact with family.
Student 14 **Father and mother: Beauty shop owner.** **13Y09M Female** **TV/book/ Magazine/ computer**	Yes.	Ground shaking.	People are running away, things are shaking.	10-20 seconds.	Before: Not sure. During: Shaking. After: Check the building structure.	Plate tectonic.	Insensible earthquakes: Many times a day. Sensible earthquakes: Below 5-6/year.	Circum Pacific belt and Atlantic belt.	Taiwan only.	Yes, I am afraid of strong one, because I may get hurt.	Before: Prepare food, water, and torch. After: Try to help others.
Student 15 **Father: Public servant Mother: Unknown job** **12Y10M Male** **TV/film/ Book/ newspaper computer**	No.	Plate tectonic.	Things are falling down, ground surface break up.	1-2 minutes.	No ideas.	Plate tectonic.	Insensible earthquakes: Many times a day. Sensible earthquakes: Below 5-6/year.	Japan, Taiwan and USA.	No.	No, because I don't feel any big change.	Before: Put ant important document in a safe place. After: Help other people if I can.
Student 16 **Father: Taxi driver Mother: Technician** **13Y05M Female** **TV/film Video/ Book/ Comic/ Newspaper/ Magazine/ Computer**	Yes, earthworm would be out of the earth 1-2 days before it happens.	Plate tectonic.	Walls are breaking off and everything is shaking.	1-2 minutes.	Before: Animals have extraordinary behavior. During: Earth surface is shaking. After: Houses are falling down.	Plate tectonic.	Insensible earthquakes: 100/year. Sensible earthquakes: 4-5/year.	Taiwan, USA, Japan, and the place between China and India.	Taiwan only.	No, I feel ok, I don't not think it is a big deal.	Before: Try to add shake resistant structure in the building. After: Re-construct the weak buildings.

Student 17 **Father: A staff in radio company. Mother: Primary school teacher.** **12Y09M Male** **TV/film Video/ Book/ Newspaper/ Magazine Computer**	No.	Plate shake from up and down direction to left and right direction.	Things are falling down and moving around.	30 minutes.	No ideas.	Plate movements.	Insensible earthquakes: Many times a day. Sensible earthquakes: 7-8/year.	Japan, Taiwan, North India, Africa and North America.	Taiwan only.	No, because I am not afraid of death.	Before: Remove any object from high position. After: No ideas.
Student 18 **Father and mother: Businessman** **12Y05M Female** **TV/film Video/ Book/ Newspaper/ Magazine/ Computer**	Yes, mice would run out of their nest few days before it happen.	Earth crust movement.	Water and lamps are shaking.	20-30 seconds.	Before: Sometimes there is some ground sound. During: Strong shaking. After: Things are in disorder.	Earth crust slide and shear off.	Insensible earthquakes: Many times a day. Sensible earthquakes: 2-3/year.	Circum Pacific belt.	Yes, in Singapore, I feel nothing very different, but earthquakes in Taiwan is stronger.	No, I feel ok, because I don't think it is very serious to me.	Before: Strengthen the building structure. After: Keep strengthen the structure if it is necessary.
Student 19 **Father: Designer. Mother: Housewife.** **12Y05M Female** **TV/film Video/ Book/ Newspaper/ Magazine/ Computer**	Yes, by detecting seismic waves.	Plate tectonic.	Mud flow could be touched off, and comes after many natural hazards.	Half hour.	Before: Mild shaking. During: Main shaking. After: Many thing fall down on the floor.	Plate tectonic.	Insensible earthquakes: Many times a day. Sensible earthquakes: Up to 10/year.	Far East, Green land and Circum Pacific belt.	Taiwan only.	Yes, because I can not afford serious damage and I may losing life.	Before: Build good foundations for new houses. After: to deal with problems and difficulties.

Student 20 **Father: Self-employer** **Mother: Housewife.** **12Y04M** **Female** **TV/film** **Video/** **Book/** **Newspaper/** **Computer**	Yes.	No ideas.	Many buildings are falling down.	In 1 minute.	Before: No ideas. During: Shaking. After: Many buildings are falling down.	Meteorite hit or plate tectonic.	No ideas.	Taiwan.	Taiwan only.	Yes, I am afraid if things fall down and hit my head.	No ideas.
Student 21 **Father And Mother: Businessman** **13Y01M** **Female** **TV/film** **Video/** **Book/** **Newspaper/** **Magazine** **Computer**	Yes.	Ground shaking.	Houses fall down.	2 minutes.	Before: Mild shaking. During: People are running away, because there is a strong one. After: I don't really now.	Plate tectonic.	No ideas.	Taiwan, Japan and Korea.	Taiwan only.	No, even for 921 earthquake event, I am not afraid of it, because I think my house is strong enough.	No ideas.
Student 22 **Father: No job.** **Mother: Bakery staff.** **12Y03M** **Male** **TV/film/** **Book** **Newspaper** **computer**	No.	Plate tectonic.	Ground shaking, if it is very strong, things and buildings will fall down on the ground.	In 10 minutes.	Before: Animals have extraordinary behavior. During: Shaking. After: A lot of broken things.	Plate rug against to each other.	Insensible earthquakes: Many times a day. Sensible earthquakes: 1/year.	Taiwan and USA.	Taiwan only.	No, because I realize the situation, and I believe I can handle it.	Before: Put glass in a lower position or to be protected by something. After: Re-build the area.

Student 23 **Father: No job** **Mother: Worker.** **11Y10M** **Female** **Film Video/ Book/ Newspaper/ computer**	No.	Plate tectonic and cause ground shaking.	Houses and things are falling down.	In 1 minute.	Before: Animals have extraordinary behavior. Ant are moving away. During: Shaking. After: A lot of things damaged.	Plate tectonic.	Insensible earthquakes: Many times a day. Sensible earthquakes: 3/year.	Circum Pacific belt.	Taiwan only.	Yes, because things fall down and people may get hurt.	Before: Prepare AID box and fix everything. After: Improve building structure.
Student 24 **Father: Service trade** **Mother: Housewife** **12Y07M** **Female** **TV/book/ Newspaper**	Yes, there should be some earthquake period.	The asthenosphere carry crust to do the movements.	Houses fall down and crust may split up or bulge up.	In 1 minute.	Before: Animals have extraordinary behavior. Earthworm will come out of the ground. During: Shaking. After: We will lose power.	Plate tectonic.	Insensible earthquakes: Many times a day. Sensible earthquakes: 10/year.	Circum Pacific belt. And North America.	Taiwan only.	No, because I have never experienced a strong one.	Before: Fix everything properly. Switch off power source and open the door. After: Check up if there is anything leak out.
Student 25 **father and mother: businessman** **12Y11M** **Female** **TV/film Video/ Book/ Comic/ Newspaper/ Magazine/ computer**	No.	Plate tectonic.	Shaking.	Few minutes.	Before: No ideas. During: Shaking. After: Ground split up.	Earth internal heat convection.	Insensible earthquakes: Many times a day. Sensible earthquakes: Quite few, less than 2/year.	Circum Pacific and Atlantic belt.	Taiwan only.	No, because when it happened, I always fall in a sleep.	Before: Prepare medicine, food and torch. After: Try to find out the other survivors.

Appendix 8: The Understanding of Earthquakes in Senior High School Year 3

	0. Are earthquakes predictable?	1. What is an earthquake?	2. What happens during an earthquake?	3. How long does an earthquake last?	4. What does it look like before/during/after an earthquake?	5. What causes an earthquake to happen?	6. How often do earthquakes happen?	7. Where do earthquakes occur?	8. Have you ever experienced an earthquake in any other country/place?	9. Are you afraid of earthquakes?	10. What should we/you do before/during/after an earthquake?
Student 01 **Father: Technician** **Mother: Housewife** **12Y08M** **Male** **TV/film/ Video/ Book/ newspaper**	Yes, but only for very limited time.	Plate tectonic.	Things are falling down, lamps are waving.	In 1 minute.	Before: I am not sure. During: Shaking. After: Stop shaking.	Plate tectonic, Earth crust is affected by share stress.	Insensible earthquakes: All the time. Sensible earthquakes: 4-5 times a year.	The boundary between 2 plates and middle ocean ridge.	Taiwan only.	No, because I think Taipei will never experience such a great earthquake.	Before: Prepare anything to against seismic waves. After: Try to help some other people.
Student 02 **Father: Public servant.** **Mother: Housewife** **12Y08M** **Male** **TV/film/ Video/ Book/ Newspaper/ Magazine/ Computer**	No.	Plate tectonic.	Many things are shaking and falling down.	Few seconds to 1 minute.	Before: Nothing happen. During: Many things are shaking and falling down. After: There are a lot of damage from landslide.	Lava "shears" plates to move away.	Insensible earthquakes: All the time. Sensible earthquakes: Not sure but quite often.	Taiwan, Japan and somewhere between China and India.	Taiwan only.	No, because I have not got any damage from earthquakes.	Before: People should have well reaction training. After: Government should subsidize people who have houses damaged.
Student 03 **Father: Driver** **Mother: Housewife** **12Y08M** **Male** **TV/ Video/ Book/ Newspaper/ Magazine computer**	Yes.	Earth releases its energy, and it is a kind of power to destroy.	A city may lose power, trees are falling down, and everything is waving.	In 1 minute, depend on the energy.	Before: I can see a glass of water starts to shake. During: Everything is shaking. After: There are a lot of damage.	Plate tectonic, which include the movements of convergent plate and divergent plate.	Insensible earthquakes: All the time. Sensible earthquakes: 2-3/year.	Taiwan, Japan, Middle East, USA and Atlantic ocean.	Taiwan only.	If earthquakes last for long time, I will be afraid of it. If it last for short time, I am not afraid of it.	Before: To designate the assembly points and places to hide. After: If the road and bridge are damaged, government should re-open them as soon as possible.

Student 04 **Father and mother: Technician** **12Y08M** **Female** **TV/film/ Video/ Book/comic/ Newspaper/ Computer**	Yes, but not accurate.	Plate rub against to each other, Earth release its energy.	Ground shaking and people are panic.	3-5 minutes.	Before: Mild shaking. During: Strong shaking. After: Try to criticize the reaction plans and maybe modify it.	Plate tectonic.	Insensible earthquakes: All the time. Sensible earthquakes: 20/year	Far East, India, Europe, north America and South America.	USA (California) and Taiwan.	Not really, it depends on its strength.	Before: Prepare AID box, water and food. Clear up the exit. After: Try to help other people.
Student 05 **Father: Business.** **Mother: Lawyer** **12Y08M** **Male** **TV/ Book/ Newspaper/ Magazine/ computer**	Yes, by using seismograph.	Plates rub against to each other and these are caused by Earth internal energy.	Ground is shaking like boats.	Few days.	Before: Mild shaking. During: Strong shaking. After: Earth tremors come after soon.	Plate tectonic.	Insensible earthquakes: All the time. Sensible earthquakes: 1-2/year.	Circum-Pacific belt.	Taiwan only.	Not really, it depends on its strength.	Before: Prepare AID. After: Try to help other people.
Student 06 **Father: Chef** **Mother: Nurse** **12Y07M** **Male** **TV/ Video/ Book/ Newspaper/ computer**	No.	Earth releases energy and cause ground shaking.	There are two kind of seismic waves: P wave and S wave. Earthquakes cause everything shake heavily.	In 5 minutes.	Before: No feeling. During: Ground is shaking and people are panic. After: Things are falling down, houses damaged.	Plate tectonic and the movements of Earth crust, both are pushed by lava flow from mantle.	Insensible earthquakes: All the time. Sensible earthquakes: 10/year.	The boundary of two plates. Japan, Taiwan, Philippine and Atlantic ocean.	Taiwan only.	Not really.	Before: Fix everything properly. After: Try to help others.
Student 07 **Father: Sales** **Mother: Housewife** **13Y07M** **Male** **TV/film/ book/ newspaper computer**	No.	Plate tectonic.	Ground shaking.	About 10 seconds.	Before: Nothing happen. During: People are panic, things are falling down. After: Try to recover everything.	Plate tectonic.	Insensible earthquakes: All the time. Sensible earthquakes: 4-5/year.	South Asia and Circum-Pacific belt.	Taiwan only.	No I am not afraid of it.	Before: Strengthen building structure. After: To confirm if the reaction plan is proper.

Student 08 **Father and Mother: Unknown jobs** **12Y04M** **Male** **TV/film/ Video/ Book/comic/ magazine**	Yes, by detecting the energy.	Plate tectonic.	Floor is shaking and houses are falling down.	7-8 seconds.	Before: Shaking direction is from left and right to up and down. During: Houses are falling down. After: There are several Earth tremors come after.	Earth releases its energy and cause plate tectonic.	Insensible earthquakes: All the time. Sensible earthquakes: 5-6/year.	Circum-Pacific belt and Atlantic Ocean.	Taiwan only.	No I am not afraid of it.	Before: Set and fix everything properly. After: Check up if there is any damage in the area.
Student 09 **Father: Engineer** **Mother: Housewife** **12Y04M** **Male** **TV/film/ Video/ Book/ Comic/ magazine newspaper computer**	No.	Layers release energy.	Shaking.	In 10 seconds.	Before: Animals have extraordinary behavior. During: Shaking. After: Geographic view may be changed.	Plate tectonic, Earth internal power.	Insensible earthquakes: All the time. Sensible earthquakes: 50-100/year.	Circum-Pacific belt.	Taiwan only.	No, because I have never had serious damage.	Before: Prepare any life-saving stuff. After: to notice the latest news at anytime.
Student 10 **Father: Security Guard** **Mother: Pass away.** **12Y01M** **Male** **TV/film/ Video**	Yes, by detecting the frequency of energy realizing.	Plate tectonic, lava is overheat, and then cause ground shaking.	Shaking is everywhere.	10 seconds.	Before: Nothing happen. During: Ground shakes strongly. After: Landslide may happen.	Plate tectonic.	Insensible earthquakes: All the time. Sensible earthquakes: 10/year	Taiwan, Japan, and Philippines.	Taiwan only.	Yes, because I used to experienced 921 great earthquake, and I lived near by epicenter. And I might lose my life.	Before: Nothing happen, we can open the window if we know it is coming. After: Try to contact friends and family, and check if they are all right.
Student 11 **Father: Designer** **Mother: Bank staff.** **13Y 01M** **Male** **TV/film/ Video/ magazine newspaper**	No.	Plates are shaking, then cause Earth surface shaking.	Things are falling down and ground is shaking.	Few seconds.	Before: Animals have extraordinary behavior. During: Ground shaking. After: There are still some Earth tremors.	Plate tectonic, Earth realizes its energy.	Insensible earthquakes: All the time. Sensible earthquakes: 10/year	Taiwan, Japan and South-East Asia.	Taiwan only.	No, I am not worry about it.	Before: Do not put any breakable stuff in the high position. After: Put attention in the latest news.

Computer											
Student 12 **Father: Self-employer** **Mother: Housewife.** **13Y00M** **Female** **TV/book/ Comic**	No.	Plate tectonic.	People are running away, objects fall down on the floor, and the cities may lose power.	10-15 seconds.	Before: Animals have extraordinary behavior. During: Ground shaking. After: Damages are everywhere.	Plate tectonic or sea-volcanoes.	Insensible earthquakes: All the time. Sensible earthquakes: 5-7/year.	Circum-Pacific belt. Taiwan, Japan and North Africa.	USA.	No.	Before: Prepare AID kits, reaction plan and alarm system. After: Ask everyone to re-build the area together.
Student 13 **Father: Self-employer** **Mother: Housewife** **12Y11M** **Male** **TV/film/book? Newspaper/ computer**	Yes, fish can be caught more easily than usual because they would like to stay in the shallow water. There are red clouds in sky.	Everything is waving.	Everything is from strong waving to be calm.	In 1 minute.	No ideas.	Plate tectonic.	Insensible earthquakes: All the time. Sensible earthquakes: 20/year.	Japan, Taiwan, South Asia and Middle East.	Taiwan only.	No, I am getting used to it.	Before: People should have a proper survival training. After: Re-build the area.
Student 14 **Father and mother: Beauty shop owner.** **13Y09M** **Female** **TV/book/ Magazine/ computer**	No.	Plate got some sort of shear movement or broken, these are some kind of energy releasing. All of these cause ground shaking.	Landslide, road sinking, if it is very strong, cities may lose power and get fire.	In 1 minute.	Before: I feel my body start to shake. During: Everything is shaking. After: To check up every thing.	Plate tectonic.	Insensible earthquakes: All the time. Sensible earthquakes: 5-6/year.	Taiwan, Japan, North India and USA.	Taiwan only.	It all depends, if it is a quick earthquake, I am not afraid of it. But if it is a long lasting earthquake, I will be afraid of it.	Before: Do not put anything in the high position, and house foundation should be built properly. After: Government should repair the road as soon as possible.
Student 15 **Father: Public servant** **Mother: Unknown job** **12Y10M** **Male** **TV/film/ Book/ newspaper**	No.	Plate tectonic.	Building collapse and land slide.	30 seconds.	Before: Cities may lose power. During: Ground shaking. After: Many people die.	Plate tectonic.	Insensible earthquakes: All the time. Sensible earthquakes: 1/year.	Japan, Taiwan, China, Mongolia, Middle East and center America.	Taiwan only.	Yes, I am afraid of strong earthquake, because this mat take my life away.	Before: The house need good structure. After: Strength the weak building.

computer											
Student 16 **Father: Taxi driver** **Mother: Technician** **13Y05M** **Female** **TV/film Video/ Book/ Comic/ Newspaper/ Magazine/ computer**	No.	Plate tectonic and Earth releases its energy.	Houses are falling down.	30 seconds to 1 minute.	Before: Nothing happen. During: Many things are shaking. After: Houses are falling down.	Plate tectonic.	Insensible earthquakes: All the time. Sensible earthquakes: 6-7/year.	Far East and north America.	Taiwan only.	Yes, because everything is damaged by earthquakes.	Before: Prepare medicine and try to strengthen building structure. After: Rebuild the area.
Student 17 **Father: A staff in radio company.** **Mother: Primary school teacher.** **12Y09M** **Male** **TV/film Video/ Book/ Newspaper/ Magazine Computer**	No.	Ground shaking.	Lamps are waving, internet breaks down and cities lose power.	Few seconds.	Before: Animals have extraordinary behavior. During: Ground shaking. After: There are still some Earth tremors.	Plate tectonic.	Insensible earthquakes: All the time. Sensible earthquakes: Not sure.	Japan, Taiwan, Australia, middle East and Atlantic ocean.	Taiwan only.	Yes, because it comes in a sudden and unexpectableable.	Before: Prepare water, food, and AID kits. After: Rebuild the area.
Student 18 **Father and mother: Businessman** **12Y05M** **Female** **TV/film Video/ Book/ Newspaper/ Magazine/ Computer**	Yes.	Plate tectonic.	A lot of damages.	In 1 minute.	No ideas.	Plate tectonic and orogenesis.	Insensible earthquakes: All the time. Sensible earthquakes: 3/year.	Japan, Taiwan, Africa, Circum-Pacific belt, north and center America.	Taiwan only.	No, I am getting used to it.	Before: Prepare AID kits. During: Switch off power, stay under a table or go to an open area. After: No ideas.

Student 19 **Father: Designer.** **Mother: Housewife.** **12Y05M** **Female** **TV/film** **Video/** **Book/** **Newspaper/** **Magazine/** **computer**	Yes, because animals have unusual reactions .	Earth crust rubs against to each other.	People are panic, things are falling down.	For strong one: 3-5 minutes. For mild one: 20-30 seconds.	Before: Mild shaking. During: Strong shaking. After: Stop shaking.	Earth crust rubs against to each other.	Insensible earthquakes: All the time. Sensible earthquakes: 5-15/year.	Circum-Pacific belt, and north India.	Taiwan only.	Only afraid of strong earthquakes .	Before: Prepare: AID kits, food. After: Use the above things properly.
Student 20 **Father: Self-employer** **Mother: Housewife.** **12Y04M** **Female** **TV/film** **Video/** **Book/** **Newspaper/** **computer**	No.	Broad area shaking.	Cars are forced to pull over.	1-2 minutes.	Before: Mild shaking. During: Strong shaking. After: Everything calm down.	All plates move to a new balanced position.	Insensible earthquakes: All the time. Sensible earthquakes: Not sure.	Circum-Pacific belt, and north India	Japan, I feel nothing different.	Yes, because nobody knows when it could happen.	Before: Strengthen the buildings and prepare everything needed. After: Check the building structure, incase it needs to be strengthen again.
Student 21 **Father And Mother: Businessman** **13Y01M** **Female** **TV/film** **Video/** **Book/** **Newspaper/** **Magazine** **computer**	Yes, fish would like to stay in the shallow water, many people call it as "earthquake fish".	Ground shaking.	People are shouting, things are falling down.	10 seconds.	Before: Mild shaking. During: Strong shaking. After: Everything calm down.	Earth releases its energy.	Insensible earthquakes: All the time. Sensible earthquakes: 2/year.	Japan, Taiwan, Madagascar, center and south America..	Taiwan only.	No, because I feel no damage to me.	Before: Strengthen the buildings and prepare everything needed. Read or learn more things about earthquakes. After: Rebuild the whole area.
Student 22 **Father: No job.** **Mother: Bakery staff.** **12Y03M** **Male** **TV/film/** **Book** **Newspaper** **computer**	No.	Earth releases its internal energy.	Ground shaking and people are screaming.	1 minute.	Before: Mild shaking. During: Strong shaking. After: Several Earth tremors come after.	Plate tectonic.	Insensible earthquakes: All the time. Sensible earthquakes: 2/year.	Far East, south Asia, east Africa, north America and south America.	Taiwan only.	No, because I feel no damage to me.	Before: Strengthen building structure. After: Rebuild the area and rebuild everybody's mind.

Student 23 **Father: No job** **Mother: Worker.** **11Y10M Female** **Film Video/ Book/ Newspaper/ computer**	Yes, by detecting very mild shaking.	Plate tectonic.	Ground shaking.	1-2 minutes.	No ideas.	Plate tectonic.	Insensible earthquakes: All the time. Sensible earthquakes: 20/year.	Taiwan and Japan.	Taiwan only.	No, because I am getting used to it.	Before: Do not put anything in high position. During: Go to an open place. After: No ideas.
Student 24 **Father: Service trade** **Mother: Housewife** **12Y07M Female** **TV/book/ Newspaper**	No.	Earth crusts rib against to each other.	None, nothing special.	10 minutes.	Before: Nothing happen. During: Shaking. After: Nothing happen but damage.	Earth crusts rib against to each other.	Insensible earthquakes: All the time. Sensible earthquakes: 1/year.	Taiwan and Japan.	Taiwan only.	No, because in most time when it happened, I was sleeping.	Before: No ideas. After: Try to help others.
Student 25 **father and mother: businessman** **12Y11M Female** **TV/film Video/ Book/ Comic/ Newspaper/ Magazine/ computer**	No.	Ground shaking.	Everything is shaking, and building are falling down.	1 minute.	No ideas.	Faults slide to one particular direction.	Insensible earthquakes: All the time. Sensible earthquakes: 2-3/year.	Japan, Taiwan east Africa, center and south America.	Taiwan only.	Yes, a little bit, because building may fall down.	Before: Fix everything well, strengthen building structure. After: No ideas.

Appendix 9: The Understanding of Combined Events in Primary School Year 3

	1. Are earthquakes and volcanoes linked in any way? And could you tell me the reason(s)	**2. How do you regard volcanic activities in Taiwan? (For example: is it a kind of natural resource, a kind of energy or it is just an unavoidable hazard? Could you explain why you think so?)**	**3. How do you regard earthquakes in Taiwan? (For example: Is this a natural hazard or a necessary energy release?)**	**4. How do you think of the current status of volcano in Taiwan?**	**5. How do you think of the status of earthquake in Taiwan and around the world?**
Student 01 **Father and mother: Businessman** **10Y09M** **Male** **TV/film/ Video/ Book/ Comic/ Newspaper/ Magazine/ Computer**	Yes, I think volcanic eruptions can cause earthquakes to happen and vice versa. The only link between these two events is earth surface.	I think it is a natural resource, because it has not erupted for long time, the only thing can be seen is hot spring water, and this is very useful resource.	Of course a natural hazard, because it always left the damage.	Dead volcanoes, because they have not erupted for long time.	Japan is the most serious damage place for earthquakes all over the world. But in Taiwan, the strength of earthquakes from strong to weak are: East, West, North, South. The damage of earthquakes from strong to weak are: East, West, North, South.
Student 02 **Father: Businessman.** **Mother: Secondary teacher.** **10Y03M** **Male** **TV/ Video/ Newspaper/ Computer**	Yes, I think volcanic eruptions can cause earthquakes to happen and vice versa. The only link between these two events is shaking.	I think it is a natural resource, because it has not erupted for long time, the only thing can be seen is hot spring water, and it is useful for taking a bath.	They are both natural hazard and energy release, they are hazard because they left damage, they are energy because of shaking.	In North Taiwan for example: Mt. Yang Ming is a dead volcano. I am not sure about others, but presumably there are still some live and dormant volcanoes.	The strongest earthquakes occur in the Himalayas. But in Taiwan, the strength of earthquakes from strong to weak are: East, West, South, North. The damage of earthquakes from strong to weak are: East= West, North= South.
Student 03 **Father: Corresponde nt** **Mother: Businesswom an** **09Y06M** **Male** **TV/ Video/ Book/Newspa per/ Magazine**	No.	I think it is a natural resource, because it has not erupted for long time, the only thing can be seen is hot spring water, and it is useful for taking a bath.	I think they are natural hazards, because they cause houses falling and many people losing lives.	Dead volcanoes.	The most serious and frequent earthquakes area is Taiwan, the strength of earthquakes from strong to weak are: East= West, North, South. The damage of earthquakes from strong to weak are: No ideas.

Student 04 **Father and mother: Businessman** **10Y02M** **Male** **TV/ Book/ Newspaper/**	Yes, earthquakes cause volcanic events by shaking, and volcanic eruptions cause earthquakes by eruptional force.	I think it is a natural resource, because it has not erupted for long time, the only thing can be seen is hot spring water, and it is useful for taking a bath.	It is a kind of hazard, because it left a lot of damage.	Dead volcanoes.	No ideas at all.
Student 05 **Father: Engineer** **Mother: Housewife** **10Y04M** **Female** **TV/ Video/ Comic/ Computer**	Yes, but I can not explain anything, it is just my feeling.	Is a natural resource.	Is a necessary energy release by shaking.	No ideas.	Taiwan has the most serious earthquakes around the world. But I am not sure the status of earthquake in Taiwan.
Student 06 **Father: Businessman** **Mother: Housewife** **09Y10M** **Female** **TV/Book/newspaper.**	Yes, but only earthquakes can cause volcanic eruptions but volcanic eruptions can not cause earthquakes to happen.	I think it is a unavoidable hazard, because the power of lava and stone are unavoidable.	I feel it is a sort of natural resource but I don't know the reason.	Dead volcanoes, because they have not erupted for long term.	I think most earthquakes happen in Taiwan, the strength of earthquakes from strong to weak are: West, East, North, South. The damage of earthquakes from strong to weak are: No ideas.

Student 07 **Farther: Businessman** **Mother: Service trade** **09Y11M** **Female** **TV/film/ Video/ Book/ Comic/ Newspaper/**	No.	There is no volcanic activity in Taiwan.	It is a natural hazard, because it damages a lot of things.	I don't think there is any volcanic activity in Taiwan.	There is a lot of earthquakes in Japan, but in Taiwan the strength of earthquakes from strong to weak are: East, West, South, North. The damage of earthquakes from strong to weak are: East, West, South, North.
Student 08 **Father and mother: Unknowing job.** **10Y00M** **Male** **TV/ book/ newspaper**	No ideas.	No ideas.	It is a natural hazard.	No ideas.	I don't know the status of earthquake around the world, but in Taiwan the strength of earthquakes from strong to weak are: East, West. The damage of earthquakes from strong to weak are: East, West, South, North.
Student 09 **Father and mother: Secondary teacher.** **09Y11M** **Male** **TV/book/ Magazine**	No.	No idea.	It is a natural hazard which relate to the movement oceanic crust.	No idea.	Taiwan is the most frequent area of earthquakes. In Taiwan the strength of earthquakes from strong to weak are: West, East, South, North. The damage of earthquakes from strong to weak are: No idea.
Student 10 **Father and mother: Businessman.** **09Y08M** **Male** **TV/film/ Book/ Comic/ Newspaper/**	Yes, I think Earthquakes cause volcanic eruptions by crust cracking and vise versa.	No idea.	It is a natural hazard, because it damages a lot of things.	No idea.	USA has the most serious earthquakes in the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, South, North. The damage of earthquakes from strong to weak are: East, West, South, South, North.

Student 11 **Father: Businessman** **Mother: Housewife** **09Y10M** **Male** **TV/ Video/ Book/ Comic/ Magazine**	No.	No idea.	It is a natural hazard because walls are broken.	No idea.	I am not sure the status of earthquake around the world but in Taiwan the strength of earthquakes from strong to weak are: West, East, South, North. The damage of earthquakes from strong to weak are: West, East, South, North.
Student 12 **Father and mother: Businessman.** **09Y00M** **Male** **Film/ Video/ Book/ Newspaper/ Magazine**	Yes, but I don't know the reason.	No idea.	No idea.	No idea.	Brazil is the most frequent place of earthquakes in the world. In Taiwan the strength of earthquakes from strong to weak are: South, North. The damage of earthquakes from strong to weak are: East, West, North, South.
Student 13 **Father: Businessman** **Mother: Housewife** **09Y05M** **Female** **TV/film/ Book/ Newspaper/ Computer**	Yes, earthquakes can cause volcanic eruptions by ground shaking, and volcanic eruptions cause earthquakes to happen by heat (because heat can make stone broken).	It is a natural resource, especial for hot spring water.	It is a natural hazard, because many people lose their lives.	Dead volcanoes.	Taiwan is the most serious place of earthquake events. In Taiwan the strength of earthquakes from strong to weak are: West, East, South, North. The damage of earthquakes from strong to weak are: West, East, South, North.

Student 14 **Father: Designer Mother: Housewife** **09Y03M Female** **TV/ Book/ Newspaper/ computer**	No.	It is a natural resource, such as hot spring water.	It is a natural hazard, because it left a lot of damages.	Dead volcanoes.	There are a lot of earthquakes happen in Taiwan. In Taiwan the strength of earthquakes from strong to weak are: East, West, South, North. The damage of earthquakes from strong to weak are: East, West, South, North.
Student 15 **Father and mother: Secondary teacher** **09Y08M Female** **TV/film/ Video/ Book/ Newspaper/ Computer**	Yes, but only volcanic eruptions can cause earthquakes to happen (by ground shaking).	No idea.	It is a natural hazard because it makes houses falling down.	No idea.	Iraq should be the most serious place of earthquakes events. In Taiwan the strength of earthquakes from strong to weak are: East, West, North South. The damage of earthquakes from strong to weak are: East, West, North, South.
Student 16 **Father and mother: Unknown jobs** **09Y08M Female** **TV/ newspaper/ computer**	Yes, but I don't know the reason, I just feel like that.	No idea.	It is a natural hazard because many people lose their life.	No idea.	Taiwan is the most frequent area of earthquake events, in Taiwan the strength of earthquakes from strong to weak are: East, West, North South. The damage of earthquakes from strong to weak are: West, East, North, South.
Student 17 **Father and mother: Businessman.** **09Y07M Female** **TV/book/ Newspaper/ Computer.**	No.	No idea.	It is a natural hazard, but it is hard to explain why.	No idea.	I don't know the status of earthquake around the world, but in Taiwan the strength of earthquakes from strong to weak are: West, East, North South. The damage of earthquakes from strong to weak are: East, West, North,

					South.
Student 18 **Father: Businessman. Mother: Housewife.** **Y0910M Female** **TV/ Book/ newspaper**	Yes.	No idea.	It is a kind of resource.	No idea.	No idea about the status of earthquake around the world, but in the strength of earthquakes from strong to weak are: East, West, South, North. The damage of earthquakes from strong to weak are: No idea.
Student 19 **parents: pass away. Uncle: Chef Aunt: Housewife** **09Y06M Female** **TV/film/ Video/ Book/ Newspaper/ Magazine**	Yes, volcanic eruptions can cause earthquakes to happen by ground shaking, and vise versa.	No idea.	It is a natural hazard, because it damages many things.	No idea.	Japan is the most serious area of earthquake events. In Taiwan the strength of earthquakes from strong to weak are: West, East, South, North. The damage of earthquakes from strong to weak are: No idea.
Student 20 **Father and mother: Businessman** **09Y06M Female** **TV/film/ Book**	No idea.	No idea.	It is a natural hazard, because many things fall down.	No idea.	No idea.

Student 21 **Father: Worker** **Mother: Catering trade.** **09Y05M** **Female** **TV/ Book**	Yes, but I am not sure which one cause which one to happen.	No idea.	It is a natural hazard, because many houses fall down.	No idea.	USA is the most serious area of earthquake events. In Taiwan the strength of earthquakes from strong to weak are: West, East, South, North. The damage of earthquakes from strong to weak are: West, East, South, North.
Student 22 **Father: Self-employer** **Mother: Service trade** **09Y01M** **Female** **TV/film/ Book**	Yes, but only earthquakes could cause volcanic eruptions to happen by ground shaking.	No idea.	It is a natural hazard, because many people die by this sort of event.	No idea.	Taiwan is the most serious area of earthquake events. But I have no detailed idea about the status of earthquake in Taiwan.
Student 23 **Father: Military officer** **Mother: Nurse** **09Y08M** **Female** **TV/book/ Newspaper/ Magazine**	Yes, but only earthquakes can cause volcanic eruptions to happen by ground shaking.	I think it is a kind of natural resource but I can not tell the reason.	It is a natural hazard, because many houses fall down.	They are dormant volcanoes, because they have not erupted for long term, and in fact, there is no real dead volcanoes.	I think Taiwan is the most serious place of earthquake events. In Taiwan the strength of earthquakes from strong to weak are: East, West, North, South. The damage of earthquakes from strong to weak are: West, East, North, South.

Student 24 **Father and mother: Unknown jobs** **09Y08M Female** **TV/film/ Video/ Newspaper/ Magazine/ computer**	Yes, but I am not sure the reason about it, I just feel like that.	No idea.	It is a natural hazard, because the shaking is so heavy, and cause many damages.	No idea.	Taiwan is the most frequent area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, South, North. The damage of earthquakes from strong to weak are: West, East, South, North.
Student 25 **Father and mother: Business Company staffs.** **09Y00M Female** **TV/book**	No.	No idea.	No idea.	No idea.	No idea.

Appendix 10: The Understanding of Combined Events in Primary School Year 6

	1. Are earthquakes and volcanoes linked in any way? And could you tell me the reason(s)	2. How do you regard volcanic activities in Taiwan? (For example: is it a kind of natural resource, a kind of energy or it is just an unavoidable hazard? Could you explain why you think so?)	3. How do you regard earthquakes in Taiwan? (For example: Is this a natural hazard or a necessary energy release?)	4. How do you think of the current status of volcano in Taiwan?	5. How do you think of the status of earthquake in Taiwan and around the world?
Student 01 **Father: Technician** **Mother: Housewife** **12Y08M** **Male** **TV/film/ Video/ Book/ newspaper**	Yes, Earthquakes may cause volcanic eruptions to happen by the movements of plate tectonic, but volcanic eruptions can not cause earthquakes to happen.	It is a natural resource such as gas.	It is a natural hazard, because a lot of houses damaged, it is also a necessary energy release, but I can not tell the reason.	They are dead volcanoes.	Taiwan must be the most serious area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: West, South, East, North. The damage of earthquakes from strong to weak are: South, West, North, East.
Student 02 **Father: Public servant.** **Mother: Housewife** **12Y08M** **Male** **TV/film/ Video/ Book/ Newspaper/ Magazine/ Computer**	Yes, Earthquakes may cause volcanic eruptions to happen by the movements of plate tectonic, but volcanic eruptions can not cause earthquakes to happen.	It is an unavoidable hazard.	It is a natural hazard, because many people get hurt.	They are dormant volcanoes.	China must be the most serious place of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, North, West, South. The damage of earthquakes from strong to weak are: East, North, West, South.
Student 03 **Father: Driver** **Mother: Housewife** **12Y08M** **Male** **TV/ Video/ Book/ Newspaper/ Magazine computer**	Yes, but I don't know the reason.	It is an energy, but I don't know why.	It is a natural hazard, because it always cause mud flow.	Dormant volcanoes.	Hawaii should be the most frequent place of earthquake events around the world. In Taiwan (the strength of earthquakes from strong to weak are: No ideas) The damage of earthquakes from strong to weak are: South, North, West, East.

Student 04 **Father and mother: Technician** **12Y08M** **Female** **TV/film/ Video/ Book/comic/ Newspaper/ Computer**	Yes, when the lava is being formed, it may cause earthquakes.	It is a natural resource, such as sulfur. It is a kind of energy, such as the power of eruption. And it is an unavoidable hazard as well, such as lava flow.	It is a natural hazard, because it left a lot of damage. It is also a energy release, such as waving and heat.	Dormant volcanoes.	China must be the most serious place of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: South, East, North, West. The damage of earthquakes from strong to weak are: East=West, North, South.
Student 05 **Father: Business.** **Mother: Lawyer** **12Y08M** **Male** **TV/ Book/ Newspaper/ Magazine/ computer**	No.	No idea.	It is a natural hazard, because it left a lot of damage.	Dormant volcanoes.	Japan must be the most serious place of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: South, North, West, East. The damage of earthquakes from strong to weak are: North, South, East, West.
Student 06 **Father: Chef** **Mother: Nurse** **12Y07M** **Male** **TV/ Video/ Book/ Newspaper/ Computer**	Yes, earthquakes can cause volcanic eruptions to happen by plate tectonic, but volcanic eruptions can not cause earthquakes to happen.	It is a kind of natural resource, such as volcanic scenery, it is also a kind of energy and an unavoidable hazard, because it damages a lot of thing.	It sis a hazard, because it damages many things.	Dormant volcanoes.	Taiwan is the most frequent place of earthquake events around the world. I have no ideas about the detailed status of earthquake in Taiwan.

Student 07 **Father: Sales** **Mother: Housewife** **13Y07M** **Male** **TV/film/ book/ newspaper computer**	Yes, earthquakes can cause volcanic eruptions to happen by ground shaking, but I am not sure if volcanic eruptions can cause earthquakes to happen.	It is a natural resource, such as sulfur.	It is a natural hazard, it cause mud flow.	Dormant volcanoes, because it might erupt at anytime.	Taiwan is the most serious area of earthquake eruptions around the world. In Taiwan the strength of earthquakes from strong to weak are: East, South, West, North. The damage of earthquakes from strong to weak are: East, West, North, South.
Student 08 **Father and Mother: Unknown jobs** **12Y04M** **Male** **TV/film/ Video/ Book/comic/ magazine**	Yes, earthquakes can cause volcanic eruptions to happen by ground shaking, but I am not sure if volcanic eruptions can cause earthquakes to happen.	It is a energy, because we can use terrestrial heat to generate electric power.	It is a hazard, such as 921 earthquake is a very serious damage.	Not sure, but should be dormant volcanoes.	I am not sure the status of earthquake around the world. But in Taiwan the strength of earthquakes from strong to weak are: East, South, West, North. The damage of earthquakes from strong to weak are: East, South, West, North.
Student 09 **Father: Engineer** **Mother: Housewife** **12Y04M** **Male** **TV/film/ Video/ Book/ Comic/ magazine newspaper Computer**	Yes, but I am not sure why.	It is a natural resource. We can understand the volcanic landscape well.	It is a natural hazard, because it damages many things.	Dormant volcanoes.	Taiwan is the most serious place of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: West, South, East, North. The damage of earthquakes from strong to weak are: West, South, East, North.
Student 10 **Father: Security Guard** **Mother: Pass away.** **12Y01M** **Male** **TV/film/ Video**	Yes, earthquakes may cause volcanic eruptions.	It is a kind of energy, such as terrestrial heat.	It is a natural hazard, because it cause mud flow.	Some are dead volcanoes (Mt. Yun-Min), and some are dormant volcanoes.	Japan is the most serious place of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: South, North, East, West. The damage of earthquakes from strong to weak are: South, North, East, West.

Student 11 **Father: Designer** **Mother: Bank staff.** **13Y 01M** **Male** **TV/film/ Video/ magazine newspaper Computer**	Yes, earthquakes may cause volcanic eruptions to happen by shaking, and vise versa	No idea.	It is a natural hazard, it damages a lot of things.	No idea.	Taiwan is the most serious area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: South, North, West, East. The damage of earthquakes from strong to weak are: South, East, West, North.
Student 12 **Father: Self-employer** **Mother: Housewife.** **13Y00M** **Female** **TV/book/ Comic**	Yes, volcanic eruptions could cause earthquakes to happen, but I am not sure about the reason.	It is an unavoidable hazard, it might erupt at anytime.	It is a natural hazard and also energy release, because houses fall down and ground shakes.	Live volcanoes.	Japan is the most serious place of earthquake events. In Taiwan the strength of earthquakes from strong to weak are: East, West, North, South. The damage of earthquakes from strong to weak are: East, North, West, South.
Student 13 **Father: Self-employer** **Mother: Housewife** **12Y11M** **Male** **TV/film/book ? Newspaper/ computer**	Yes, I think the two activities effect to each other by earth internal movements.	It is a kind of energy, we can use terrestrial heat to generate the electrical power.	It is a natural hazard, because it affects people's life.	There are more dead volcanoes than dormant volcanoes.	The Philippines is the most frequent place of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, South, North, West. The damage of earthquakes from strong to weak are: South, East, North, West.
Student 14 **Father and mother: Beauty shop owner.** **13Y09M** **Female** **TV/book/ Magazine/ Computer**	Yes, I think the two activities effect to each other by ground shaking and crust movement.	It is a natural resource, we can use igneous rocks for construction.	It is a natural hazard, it damages everything.	Some are dead volcanoes (Mt. Yun-Min), and some are dormant volcanoes.	China is the most frequent area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, North, South. The damage of earthquakes from strong to weak are: North, East, West, South.

Student 15 **Father: Public servant Mother: Unknown job** **12Y10M Male** **TV/film/ Book/ newspaper computer**	Yes, I think the two activities effect to each other by ground shaking and crust movement.	I think hot spring is one of the volcanic resources.	It is a hazard, may houses fall down.	Dormant volcanoes.	Taiwan is the most frequent place of earthquakes events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, North, South. The damage of earthquakes from strong to weak are: North, East, West, South.
Student 16 **Father: Taxi driver Mother: Technician** **13Y05M Female** **TV/film Video/ Book/ Comic/ Newspaper/ Magazine/ computer**	Yes, I think the two activities effect to each other by ground shaking and crust movement.	I feel it is a natural resource, but I can not tell the reason. But it is also an unavoidable hazard, because lava is so hot.	It is a hazard, may houses fall down	Dormant volcanoes.	Japan and Taiwan are both the most serious area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: South, North, East, West. The damage of earthquakes from strong to weak are: South, North, East, West.
Student 17 **Father: A staff in radio company. Mother: Primary school teacher.** **12Y09M Male** **TV/film Video/ Book/ Newspaper/ Magazine Computer**	Yes, I think the two activities effect to each other by plate tectonic.	Hot spring is one of the resources.	It is a hazard, it damages almost everything.	Dead volcanoes.	China is the most serious area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: South, East, West, North.

Student 18 **Father and mother: Businessman** **12Y05M** **Female** **TV/film** **Video/** **Book/** **Newspaper/** **Magazine/** **Computer**	Yes, I think the two activities effect to each other by plate tectonic.	It is a natural resource, volcanic mud can be used as makeup and igneous rocks can be used for construction. It is a hazard as well, because lava can destroy everything.	It is a hazard, because many people lose their life.	Dormant volcanoes.	Euro-Asia continental is the most serious place of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East North, South, West. The damage of earthquakes from strong to weak are: East, North, South, West.
Student 19 **Father: Designer.** **Mother: Housewife.** **12Y05M** **Female** **TV/film** **Video/** **Book/** **Newspaper/** **Magazine/** **Computer**	Yes, but I don't know the connection.	It is an unavoidable hazard.	It is a hazard, because houses fall down and it is also a energy release, but I can not tell the detail.	Dormant volcanoes.	Taiwan should be the most serious place of earthquake events, especially for 921 earthquake event. In Taiwan the strength of earthquakes from strong to weak are: South, East, West, North. The damage of earthquakes from strong to weak are: South, East, West, North.
Student 20 **Father: Self-employer** **Mother: Housewife.** **12Y04M** **Female** **TV/film** **Video/** **Book/** **Newspaper/** **Computer**	Yes, earthquakes can cause volcanic eruptions to happen by ground shaking.	It is a hazard and also a kind of energy, volcanic eruptions bring a lot of heat.	It is a natural hazard, a lot of people lose their life.	Dormant volcanoes.	Asia is the most frequent area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: North, East, West, South. The damage of earthquakes from strong to weak are: North, East, West, South.

Student 21 **Father And Mother: Businessman** **13Y01M** **Female** **TV/film Video/ Book/ Newspaper/ Magazine computer**	Yes, earthquakes can cause volcanic eruptions to happen by ground shaking.	No idea.	It is a natural hazard, because a lot of things are damaged.	No idea.	I don't know the status of earthquake around the world. In Taiwan the strength of earthquakes from strong to weak are: South, West, East, North. The damage of earthquakes from strong to weak are: South, West, East, North.
Student 22 **Father: No job.** **Mother: Bakery staff.** **12Y03M** **Male** **TV/film/ Book Newspaper computer**	Yes, volcanic eruptions could cause earthquakes to happen, but I am not sure if earthquake can cause volcanic eruptions to happen.	No idea.	It is a natural hazard, because a lot of people lose their lives.	No idea.	China is the most frequent area of earthquake events around the world. In Taiwan the damage of earthquakes from strong to weak are: South, North, West=East.
Student 23 **Father: No job** **Mother: Worker.** **11Y10M** **Female** **Film Video/ Book/ Newspaper/ computer**	Yes, earthquakes can cause volcanic eruptions to happen by ground shaking.	It is a kind of energy.	It is a natural hazard, because many things are damaged.	Dormant volcanoes.	Taiwan is the most serious place of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: West, East, North, South. The damage of earthquakes from strong to weak are: West, East, North, South.
Student 24 **Father: Service trade** **Mother: Housewife** **12Y07M** **Female** **TV/book/ Newspaper**	Yes, but I don't know the reason.	It is an unavoidable hazard, because the eruptional power is huge.	It is a natural hazard because many things are damaged, and it is a necessary energy release as well, the energy release by ground shaking.	Dormant volcanoes.	No ideas.

Student 25 **father and mother: businessman** **12Y11M Female** **TV/film Video/ Book/ Comic/ Newspaper/ Magazine/ computer**	Yes, I think the two activities effect to each other by ground shaking and crust movement.	No idea.	It is a hazard, because many houses fall down.	No idea.	I don't know the status of earthquake around the world. In Taiwan the strength of earthquakes from strong to weak are: South, East, West, North. The damage of earthquakes from strong to weak are: South, North, East, West.

Appendix 11: The Understanding of Combined Events in Junior High School Year 3

	1. Are earthquakes and volcanoes linked in any way? And could you tell me the reason(s)	2. How do you regard volcanic activities in Taiwan? (For example: is it a kind of natural resource, a kind of energy or it is just an unavoidable hazard? Could you explain why you think so?)	3. How do you regard earthquakes in Taiwan? (For example: Is this a natural hazard or a necessary energy release?)	4. How do you think of the current status of volcano in Taiwan?	5. How do you think of the status of earthquake in Taiwan and around the world?
Student 01 **Father and mother: Businessman** **15Y01M** **Male** **TV/Film/ Video/ Book/ Newspaper/ computer**	Yes, volcanic eruptions might cause earthquakes to happen.	It is a kind of energy, such as terrestrial heat. And it is also an unavoidable hazard, because no one can tell when it is going to happen.	It is a natural hazard, because a lot of houses damaged, it is also a necessary energy release, but I can not tell the reason.	They are dormant volcanoes.	The Philippines must be the most serious area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, South, North. The damage of earthquakes from strong to weak are: East, West, South, North.
Student 02 **Father: Printing press staff.** **Mother: Housewife.** **15Y05M** **Male** **TV/film/ Video/ Book/ Comic/ Newspaper/ Magazine/ Computer**	Yes, but I don't know the detail.	It is an unavoidable hazard and a kind of energy, in fact, lava is a kind of energy.	It is a natural hazard, because many people lose lives. It is also an energy release, such as orogeny.	I don't think there is a volcano in Taiwan.	Iran must be the most serious place of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: Middle-South, North. The damage of earthquakes from strong to weak are: North, South, West, East.
Student 03 **Father: Business** **Mother: Housewife** **15Y06M** **Male** **TV/ Book/ Newspaper/ Magazine Computer**	Yes, earthquakes may cause volcanic eruptions to happen by plate tectonic, and vise versa	It is an energy and natural resource, but I don't know why. They are also unavoidable hazards, because lava is powerful.	It is a necessary energy release by ground shaking.	Dormant volcanoes.	South-East Asia should be the most frequent area of earthquake events around the world. In Taiwan (the strength of earthquakes from strong to weak are: East, West North, South. The damage of earthquakes from strong to weak are: West, East, North, South.

Student 04 **Father and mother: Businessman** **14Y09M** **Female** **TV/book/ Computer**	Yes, volcanic eruptions could cause earthquakes to happen by fault movements.	It is an unavoidable hazard as well, such as lava flow.	It is a natural hazard, because it left a lot of damage. It is also a energy release, such as waving and heat.	Dormant volcanoes.	South America must be the most serious place of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, North, South. The damage of earthquakes from strong to weak are: West, East, North, South.
Student 05 **Father: Police officer** **Mother: Nurse** **14Y06M** **Male** **Book/ Magazine/Co mputer**	Yes, volcanic eruptions can cause earthquakes to happen by plate tectonic and the movement of asthenosphere, but earthquakes can not cause volcanic eruptions to happen.	It is a natural resource because there must be some minerals formed, and eruption is kind of energy release.	It is a natural hazard, because it left a lot of damage. And it is an energy release as well.	Dead volcanoes.	Middle ocean ridge must be the most serious area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, North, South. The damage of earthquakes from strong to weak are: West, East, North, South.
Student 06 **Father and mother: Businessman** **14Y08M** **Female** **TV/video/ Book/ Magazine Computer**	Yes, volcanic eruptions can cause earthquakes to happen by plate tectonic.	It is a kind of energy and an unavoidable hazard, because many people lose their lives.	No idea.	Dormant volcanoes.	I have no idea of the status of earthquake around the world. But in Taiwan the strength of earthquakes from strong to weak are: East, West, North,=South. The damage of earthquakes from strong to weak are: East, West, North= South.

Student 07 **Father: Service trade** **Mother: Housewife** **15Y07M** **Female** **TV/film/ Video/ Book/ Newspaper/ Magazine computer**	Yes, earthquakes can cause volcanic eruptions to happen.	It is an unavoidable hazard, because many people lose their lives.	It is a natural hazard, a lot of houses fall down and mud flow always happen.	Dormant volcanoes, because it might erupt at anytime.	Japan is the most serious area of earthquake eruptions around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, North, South. The damage of earthquakes from strong to weak are: West, East, North, South.
Student 08 **Father: No job** **Mother: Businesswom an** **15Y02M** **Female** **TV/Film/ Video/ Book/ Comic/ Newspaper/ Magazine/ Computer**	Yes, earthquakes can cause volcanic eruptions to happen by plate tectonic and vice versa.	It is a energy, because we can use terrestrial heat to generate electric power.	It is a hazard, many people lose lives.	Dormant volcanoes.	Japan is the most serious place of earthquake events around the world. But in Taiwan the strength of earthquakes from strong to weak are: East= West, South, North. The damage of earthquakes from strong to weak are: West, East, South= North.
Student 09 **Father and mother: Businessman.** **15Y08M** **Male** **TV/Book/ Computer**	Yes, these two events cause each other to happen by lava and fault movements.	It is a natural resource, hot spring is very useful, and we can use terrestrial heat to generate electric power as well.	It is a natural hazard, because it damages many things.	Dead volcanoes.	Circum-Pacific Ocean is the most serious area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, South, North. The damage of earthquakes from strong to weak are: West, East, South, North.

Student 10 **Father:** **No job** **Mother:** **Factory staff.** **15Y08M** **Female** **TV/film/Video/** **Book/** **Newspaper/** **computer**	Yes, volcanic eruptions may cause earthquakes to happen by plate movements.	It is a kind of energy, such as terrestrial heat and it is a kind of nature resource as well, such as hot spring.	It is a natural hazard, because many people lose lives. And it is an energy release.	Dormant volcanoes.	South-East Asia is the most serious area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, South, North. The damage of earthquakes from strong to weak are: East, West, South, North.
Student 11 **Father and mother:** **Public servant** **15Y09M** **Female** **TV/film/video/book** **Newspaper/** **Computer**	Yes, volcanic eruptions could cause earthquakes to happen, but earthquakes can not cause volcanic eruptions to happen.	It is a kind of energy, such as terrestrial heat.	It is a natural hazard, people lose their lives and money.	Dormant volcanoes	South-East Asia is the most serious area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, South, North. The damage of earthquakes from strong to weak are: East, West, South, North.

Student 12 **Father: Businessman** **No mother** **15Y02M** **Male** **TV/film/ Video/ Book/ Newspaper/ Magazine/ computer**	Yes, I think the two activities effect to each other by earth internal movements.	It is an unavoidable hazard, it might erupt at anytime. It is also a kind of energy and an unavoidable hazard, such as terrestrial heat and lava flow.	It is a natural hazard and also energy release, because houses fall down and ground shakes.	Dead and dormant volcanoes.	Taiwan is the most serious place of earthquake events. In Taiwan the strength of earthquakes from strong to weak are: East, West, North=South. The damage of earthquakes from strong to weak are: West, East, South=North.
Student 13 **Father: Engineer** **Mother: Nurse** **15Y04M** **Male** **TV/film/ Video/ Book/ Newspaper**	Yes, I think the two activities effect to each other by earth internal movements.	It is a kind of energy, we can use terrestrial heat to generate the electrical power.	It is a natural hazard, because it affects people's life.	Dormant volcanoes.	Circum-Pacific Ocean is the most frequent area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: West, East, North, South. The damage of earthquakes from strong to weak are: East, West, South, North.
Student 14 **Father and Mother: Teacher** **15Y07M** **Male** **TV/film/ Video/ Book/ Newspaper**	Yes, I think the two activities effect to each other by plate tectonic.	It is a natural resource, such as terrestrial heat. It is also an unavoidable hazard, such as lava flow.	It is a natural hazard, it damages everything. It is an energy release as well, such as all kinds of surface movements.	Dormant volcanoes.	Circum-Pacific Ocean is the most frequent area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East= West, South, North. The damage of earthquakes from strong to weak are: East= West, South=North.

Student 15 **Father and mother: Service trade.** **15Y00M** **Female** **TV/film/ Video/ Book/ Newspaper/ computer**	Yes, I think earthquakes can cause volcanic eruptions to happen.	I think hot spring is one of the volcanic resources.	It is a hazard, may houses fall down. It is also an energy release, such as ground shaking.	Dead volcanoes.	America is the most frequent place of earthquakes events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, South, North. The damage of earthquakes from strong to weak are: West, East, North, South.
Student 16 **Father: Businessman** **Mother: Service trade** **14Y10M** **Female** **TV/film/ Video/ Book/ Newspaper/ Magazine/ Computer**	Yes, I think the two activities effect to each other by ground shaking and crust movement.	I feel it is a natural resource, for example, volcanic mud, it is a good makeup.	It is a hazard, may houses fall down and get damage. It is also an energy release.	Dormant volcanoes.	USA and China are both the most serious area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, South, North. The damage of earthquakes from strong to weak are: East, West, South, North.

Student 17 **Father: Businessman.** **Mother: Housewife.** **15Y03M** **Male** **TV/film/ Book/ Newspaper/ Magazine/ computer**	Yes, I think the two activities effect to each other by plate tectonic.	Hot spring is one of the resources.	It is a hazard, it damages almost everything.	Dormant volcanoes.	Japan is the most serious area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, North, South. The damage of earthquakes from strong to weak are: East, West, North, East.
Student 18 **Father and mother: Businessman** **14Y 03M** **Male** **TV/film/ Book/ Newspaper/ computer**	Yes, volcanic eruptions could cause earthquakes to happen by plate tectonic, but earthquakes can not cause volcanic eruptions to happen.	It is a natural resource, such as hot spring and sulfur.	It is a hazard, because many people lose their life and also ground shaking is a kind of energy release.	Dormant volcanoes.	East America is the most serious place of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, South, North. The damage of earthquakes from strong to weak are: East, West, North, South.
Student 19 **Father: A staff in insurance company** **Mother: Housewife** **15Y05M** **Male** **TV/ Book/ Magazine/ computer**	Yes, I think the two activities effect to each other by plate tectonic.	Hot spring is one of the important resources.	It is a hazard, because houses fall down and.	Dormant volcanoes.	East Pacific should be the most serious place of earthquake events, especially for 921 earthquake event. In Taiwan the strength of earthquakes from strong to weak are: East, West, South, North. The damage of earthquakes from strong to weak are: East, West, South, North.

Student 20 **Father: Self-employer** **Mother: Housewife.** **15Y03MFemale** **Book**	Yes, volcanic eruptions could cause earthquakes to happen by plate tectonic, but earthquakes can not cause volcanic eruptions to happen.	It is an unavoidable hazard, because lava flow is very power.	It is a natural hazard, a lot of people lose their life.	Live volcanoes.	Taiwan is the most frequent area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, South, North. The damage of earthquakes from strong to weak are: East, West, South, North.
Student 21 **Father: Self-employer** **Mother: Secretary** **14Y11M Male** **Book/ Computer**	Yes, earthquakes can cause volcanic eruptions to happen by plate tectonic.	It is an unavoidable hazard, because lava flow is very power.	Ground shaking is an energy release.	Dead volcanoes.	Taiwan is the most frequent area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: West= East, North=South. The damage of earthquakes from strong to weak are: East, North, South, North.
Student 22 **Father: Worker** **Mother: Certified account.** **15Y01M Male** **TV/film/video / Book/ Newspaper/ Magazine/ computer**	Yes, volcanic eruptions could cause earthquakes to happen, but I am not sure if earthquake can cause volcanic eruptions to happen.	It is a kind of energy, such as terrestrial heat.	Ground shaking is an energy release.	Dormant volcanoes.	USA is the most frequent area of earthquake events around the world. In Taiwan the damage of earthquakes from strong to weak are: West, East, South, North. The damage of earthquakes from strong to weak are: West, East, South, North.

Student 23 **Father: Salesman** **Mother: Certified account.** **14Y11M** **Female** **TV/video/ Book/ newspaper**	No.	It is a kind of energy (heat).	It is a natural hazard, because many things are damaged. And it is also an energy release, such as ground shaking.	Dormant volcanoes.	I don't know the status of earthquake around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, North, South. The damage of earthquakes from strong to weak are: East, West, South, North.
Student 24 **Father: Technician** **Mother: Interpreter** **15Y03M** **Female** **TV/film/video / Book/ Newspaper/ computer**	Yes, volcanic eruptions could cause earthquakes to happen by asthenosphere movements, but I am not sure if earthquake can cause volcanic eruptions to happen.	It is a kind of energy (heat).	It is a natural hazard because many things are damaged, and it is a necessary energy release as well, the energy release by ground shaking.	Dormant volcanoes.	Japan is the most frequent area of earthquake events around the world. In Taiwan the damage of earthquakes from strong to weak are: West= East, South= North. The damage of earthquakes from strong to weak are: West, East, South, North.
Student 25 **Father: Businessman** **Mother: Certified account.** **15Y00M** **Female** **TV/book/ Newspaper/ computer**	Yes, volcanic eruptions could cause earthquakes to happen by asthenosphere movements, but I am not sure if earthquake can cause volcanic eruptions to happen.	It is a kind of energy, We can use terrestrial heat to generate the power.	It is a necessary energy release as well, the energy release by ground shaking.	Dormant volcanoes.	Japan is the most frequent area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East= West, North=South. The damage of earthquakes from strong to weak are: West, East, South, North.

Appendix 12: The Understanding of Combined Events in Senior High School Year 3

	1. Are earthquakes and volcanoes linked in any way? And could you tell me the reason(s)	2. How do you regard volcanic activities in Taiwan? (For example: is it a kind of natural resource, a kind of energy or it is just an unavoidable hazard? Could you explain why you think so?)	3. How do you regard earthquakes in Taiwan? (For example: Is this a natural hazard or a necessary energy release?)	4. How do you think of the current status of volcano in Taiwan?	5. How do you think of the status of earthquake in Taiwan and around the world?
Student 01 **Father: Government worker** **Mother: Government worker** **17Y10M** **Male** **TV/book/newspaper/holiday**	Yes, volcanic eruptions might cause earthquakes to happen by crust movements and vice versa.	It is a kind of energy, such as terrestrial heat. And it is also an unavoidable hazard, because no one can tell when it is going to happen.	It is a natural hazard, because there is nothing useful.	They are dead volcanoes.	Taiwan must be the most serious area of earthquake events around the world. But the status of earthquake is too complex to tell.
Student 02 **Father: bank worker** **Mother: Nurse** **18Y04M** **Male** **TV/book/holiday**	Yes, volcanic eruptions might cause earthquakes to happen by lava movements and plate tectonic and vice versa.	It is an unavoidable hazard and a kind of energy, in fact, lava is a kind of energy, and terrestrial heat can be used for generating electric power.	It is a natural hazard, because no one can tell when it is going to happen.	Dormant volcanoes.	Taiwan must be the most serious place of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: Middle-South, North. The damage of earthquakes from strong to weak are: North, South, West, East.
Student 03 **Father: unknown** **Mother: Part time worker** **18Y02M** **Male** **Book/newspaper/magazine/computer**	Yes, earthquakes may cause volcanic eruptions to happen by plate tectonic, and vise versa	It is an energy and natural resource, but I don't know the detail.	It is a necessary energy release by ground shaking. And it is also a hazard, because many people lose their lives.	Dormant volcanoes.	Taiwan should be the most frequent area of earthquake events around the world. In Taiwan (the strength of earthquakes from strong to weak are: East, West, South, North. The damage of earthquakes from strong to weak are: West, East, North, South.

Student 04 **Father and mother: Service trades** **17Y10M** **Male** **TV/book/newspaper/computer**	Yes, earthquakes may cause volcanic eruptions to happen, and vise versa	It is a natural resource and also an energy.	It is a natural hazard, because it left a lot of damage.	Dormant and dead volcanoes.	Taiwan must be the most serious place of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, North, West, South. The damage of earthquakes from strong to weak are: West, East, North, South.
Student 05 **Father: Manufacturing industry** **Mother: Housewife** **18Y04M** **Male** **TV/ Magazine**	Yes, earthquakes may cause volcanic eruptions to happen by releasing all kinds of earth energy, and vise versa	It is a natural resource, and hot spring is one of them. It is also a kind of energy, such as terrestrial heat.	It is a natural hazard, because it left a lot of damage. And it is an energy release as well.	Dormant volcanoes.	Taiwan must be the most serious area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, North=South. The damage of earthquakes from strong to weak are: West, East, North= South.
Student 06 **Father: Manufacturing industry.** **Mother: Secondary teacher.** **18Y04M** **Male** **TV/book/ Newspaper/ magazine computer**	Yes, volcanic eruptions can cause earthquakes to happen by plate tectonic and vice versa.	It is a kind of energy and a natural resource, like hot spring and terrestrial heat.	It is a natural hazard.	Dormant and dead volcanoes.	I have no idea of the status of earthquake around the world. But in Taiwan the strength of earthquakes from strong to weak are: East, West, North,=South. The damage of earthquakes from strong to weak are: East, West, North= South.

Student 07 **Father and mother: Manufacturin g industry.** **18Y01M Male** **TV/Film/ Video/ book/ Comic/ Newspaper/ Magazine computer**	Yes, earthquakes can cause volcanic eruptions to happen by plate tectonic and vice versa.	It is an unavoidable hazard, because many people lose their lives.	It is a natural hazard, a lot of houses fall down and mud flow always happen.	Dormant volcanoes, because it might erupt at anytime.	Asia is the most serious area of earthquake eruptions around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, North, South. The damage of earthquakes from strong to weak are: West, East, North, South.
Student 08 **Father: police officer Mother: Housewife** **18Y08M Male** **TV/Film/ Video/ book/ Comic/ Newspaper/ Magazine/ Computer**	Yes, earthquakes can cause volcanic eruptions to happen by plate tectonic and vice versa.	It is a natural resource, because we can use terrestrial heat to generate electric power.	It is a hazard, because the power is unpredectable.	Dead volcanoes.	Taiwan is the most serious place of earthquake events around the world. But in Taiwan the strength of earthquakes from strong to weak are: East, West, South, North. The damage of earthquakes from strong to weak are: East, West, South, North.
Student 09 **Father: Technician Mother: Sales** **18Y06M Male** **Film/ Comic**	Yes, earthquakes can cause volcanic eruptions to happen by plate tectonic and vice versa.	It is a natural resource, hot spring is very useful, and we can use terrestrial heat to generate electric power as well.	It is a natural hazard, because it damages many things.	Dormant volcanoes.	USA is the most serious area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, South, North. The damage of earthquakes from strong to weak are: West, East, South, North.

Student 10 **Father: business man** **Mother: Government worker** **17Y09M** **Male** **Book/ Newspaper**	Yes, volcanic eruptions may cause earthquakes to happen by plate movements and vice versa.	It is a kind of energy, such as terrestrial heat.	Energy release.	Dormant volcanoes.	Japan is the most serious area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, South, North. The damage of earthquakes from strong to weak are: East, West, South, North.
Student 11 **Father: Driver** **Mother: International Trade company** **18Y04M** **Female** **TV/ Film Book**	Yes, volcanic eruptions may cause earthquakes to happen by plate movements and vice versa.	It is a kind of natural resource and energy, such as terrestrial heat and hot spring.	It is a natural hazard.	Dormant volcanoes	Japan is the most serious area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, North, South. The damage of earthquakes from strong to weak are: East, West, North, South.

Student 12 **Father: Businessman** **Mother: Primary teacher** **19Y03M** **Male** **Film/ Video/ Book/ Comic/ newspaper/ Magazine/ Computer**	Yes, I think the two activities effect to each other by heat convection.	It is an unavoidable hazard, it might erupt at anytime. It is also a kind of energy and a natural resource, such as hot spring.	It is a natural hazard and also energy release, because houses fall down and ground shakes.	Dormant volcanoes.	Taiwan is the most serious place of earthquake events. In Taiwan the strength of earthquakes from strong to weak are: East, West, North, South. The damage of earthquakes from strong to weak are: West, East, South, North.
Student 13 **Father: Government worker** **Mother: Housewife** **18Y07M** **Male** **TV/ Film/ Book/ newspaper**	Yes, I think the two activities effect to each other by plate tectonic.	It is a kind of natural resource, such as hot spring.	It is a natural hazard, because it affects people's life and damages buildings.	Dead volcanoes.	Circum-Pacific Ocean is the most frequent area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, North= South. The damage of earthquakes from strong to weak are: West, East, South, North.

Student 14 **Father: Cleaning company** **Mother: Businesswoman** **18Y01M** **Male** **TV/ Book/ Newspaper/ Magazine/ Computer**	Yes, volcanic eruptions could cause earthquakes to happen by plate tectonic, but earthquakes can not cause volcanic eruptions to happen.	It is an unavoidable hazard, such as lava flow.	It is a natural hazard, it damages everything. It is an energy release as well, such as all kinds of surface movements.	Dormant, dead and live volcanoes.	Middle East is the most frequent area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, South, North. The damage of earthquakes from strong to weak are: East, West, South,North.
Student 15 **Father: Police officer** **Mother: Housewife** **18Y07M** **Male** **TV/ Film/ Video/ Book/ Newspaper/ Magazine/ computer**	Yes, I think the two activities effect to each other by ground shaking and crust movement.	I think hot spring is one of the volcanic resources and terrestrial heat as well.	It is a hazard, may houses fall down. It is also an energy release, such as ground shaking.	Dormant volcanoes.	Japan is the most frequent place of earthquakes events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, South, North. The damage of earthquakes from strong to weak are: West, East, North, South.

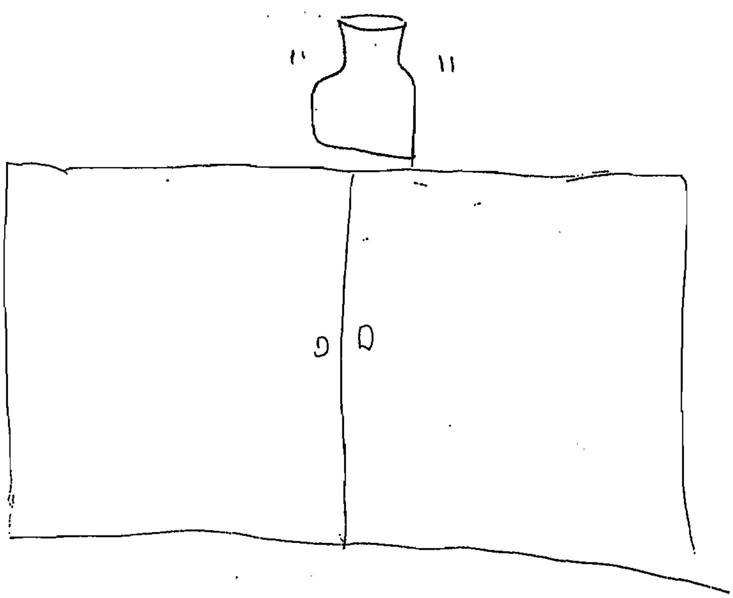
Student 16 **Father and mother: Golf Assistant** **17Y08M** **Male** **TV/Film/ Book/ Newspaper/ computer**	Yes, I think the two activities effect to each other by ground shaking and crust movement.	I feel it is a natural resource.	It is a hazard, may houses fall down and get damage. It is also an energy release.	Dormant and dead volcanoes.	The boundary between two plates is the most serious area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, North, South. The damage of earthquakes from strong to weak are: East, West, South, North.
Student 17 **Father and mother: Business man** **18Y05M** **Male** **TV/film/ Book/ Newspaper**	Yes, I think the two activities effect to each other by plate tectonic.	Terrestrial heat is a kind of energy.	It is a hazard, it damages almost everything.	Dormant volcanoes.	South-East Asia is the most serious area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, North, South. The damage of earthquakes from strong to weak are: East, West, North, South.
Student 18 **Father: Bank staff** **Mother: Warehouse assistant.** **18Y06M** **Male** **TV/film/ Book/ Newspaper/ magazine**	Yes, I think the two activities effect to each other by plate tectonic.	It is a natural resource, such as sulfur.	It is a hazard, because many people lose their life and also ground shaking is a kind of energy release.	Dead volcanoes.	North-East Asia is the most serious place of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, South, North. The damage of earthquakes from strong to weak are: East, West, North, South.

Student 19 **Father: Pathology technician** **Mother: Medical Cosmetologist** **17Y10M** **Male** **TV/film/ Video/ Book/ Comic/ Newspaper/ Magazine Computer**	Yes, I think the two activities effect to each other by plate tectonic.	Hot spring is one of the important resources and terrestrial heat can be used to generating electric power.	It is a hazard, because houses fall down and.	Dormant volcanoes.	West Pacific should be the most serious place of earthquake events, especially for 921 earthquake event. In Taiwan the strength of earthquakes from strong to weak are: East, West, South=North. The damage of earthquakes from strong to weak are: West, East South= North.
Student 20 **Father: Insurance agent** **Mother: Public servant** **18Y05M** **Male** **TV/film/ Video/ Book/ Comic/ Newspaper/ Magazine/Co mputer**	Yes, I think the two activities effect to each other by plate tectonic.	It is a resource.	It is a natural hazard, a lot of people lose their life.	Dead volcanoes.	Middle East is the most frequent area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, South, North. The damage of earthquakes from strong to weak are: East, West, South, North.

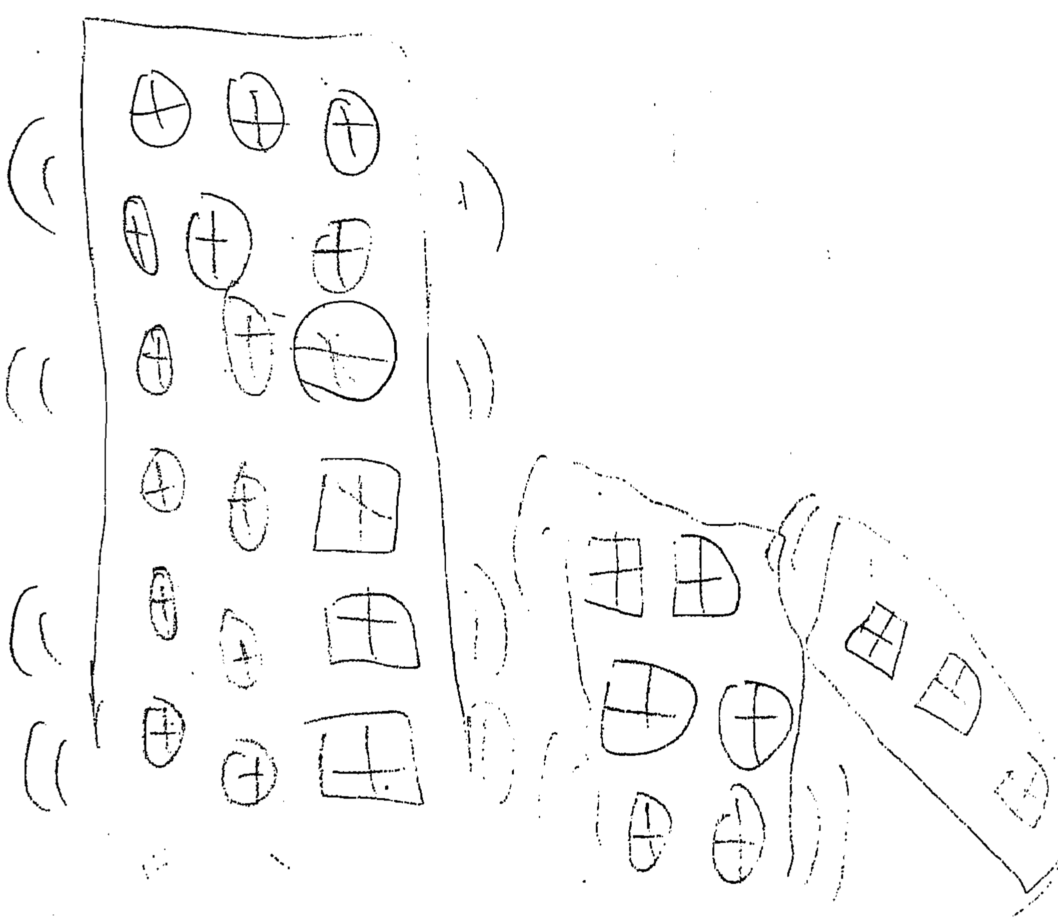
Student 21 **Father: Service trade** **Mother: Nurse** **17Y11M** **Male** **TV/film/ Video/ Book/ Comic/ Newspaper/ Magazine/Co mputer**	Yes, earthquakes can cause volcanic eruptions to happen by plate tectonic and vice versa.	It is a natural resource, such as sulfur and terrestrial heat.	Ground shaking is an energy release.	Dead volcanoes but it is possible to become live volcanoes.	South-East Asia is the most frequent area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: West= East, North,South. The damage of earthquakes from strong to weak are: East, North, South, North.
Student 22 **Father: Worker** **Mother: Housewife** **18Y05M** **Male** **TV/film/ Video/ Book/ Comic/ Newspaper/ Magazinecom puter**	Yes, I think the two activities effect to each other by ground shaking and crust movement.	It is a kind of energy and natural resource, such as terrestrial heat.	Ground shaking is an energy release. But it is also a natural hazard.	Dead volcanoes.	South-East Asia is the most frequent area of earthquake events around the world. In Taiwan the damage of earthquakes from strong to weak are: East, West, South, North. The damage of earthquakes from strong to weak are: West, East, South, North.
Student 23 **Father and mother: Businessman** **18Y02M** **Male** **TV/film/ Book/ Newspaper/ Magazine/Co mputer**	Yes, I think the two activities effect to each other by ground shaking and crust movement.	It is a kind of energy (terrestrial heat).	It is a natural hazard, because many things are damaged. And it is also an energy release, such as ground shaking.	Dead volcanoes.	West Pacific Ocean is the most frequent area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, North, South. The damage of earthquakes from strong to weak are: East, West, South, North.

Student 24 **Father and mother: Businessman** **17Y09M** **Male** **TV/ Book/ Newspaper/ Magazine**	Yes, volcanic eruptions could cause earthquakes to happen by asthenosphere movements, and vice versa.	It is a kind of energy (terrestrial heat for generating electric power).	It is a natural hazard because many things are damaged, and it is a necessary energy release as well, the energy release by ground shaking.	Dormant volcanoes.	West Pacific Ocean is the most frequent area of earthquake events around the world. In Taiwan the damage of earthquakes from strong to weak are: West= East, South= North. The damage of earthquakes from strong to weak are: West, East, South, North.
Student 25 **father and mother : businessman** **18Y05M** **Male** **TV/film/ Video/ Book/ Comic/ Newspaper/ Magazine/Computer**	Yes, volcanic eruptions could cause earthquakes to happen by asthenosphere movements, and vice versa.	It is a kind of energy, We can use terrestrial heat to generate the power.	It is a necessary energy release as well, the energy release by ground shaking.	Dormant volcanoes.	West Pacific Ocean is the most frequent area of earthquake events around the world. In Taiwan the strength of earthquakes from strong to weak are: East, West, South, North. The damage of earthquakes from strong to weak are: West, East, North, South.

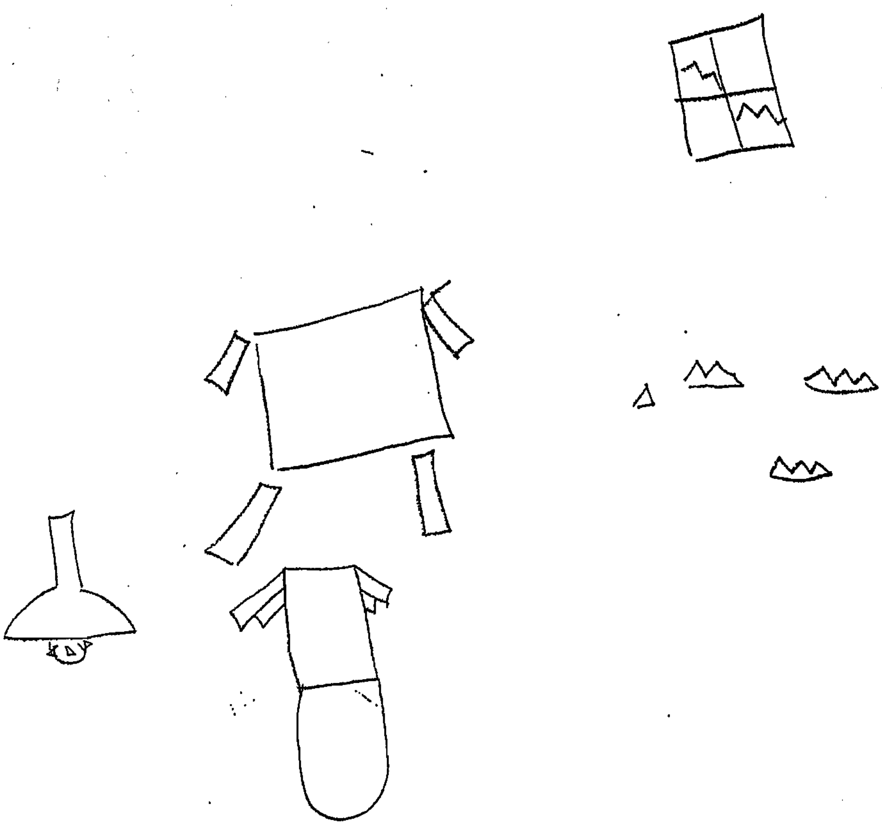
Appendix 13 An Earthquake/Primary Year 3



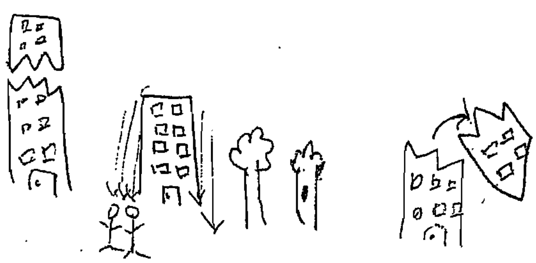
Appendix 14 An Earthquake/Primary Year 3



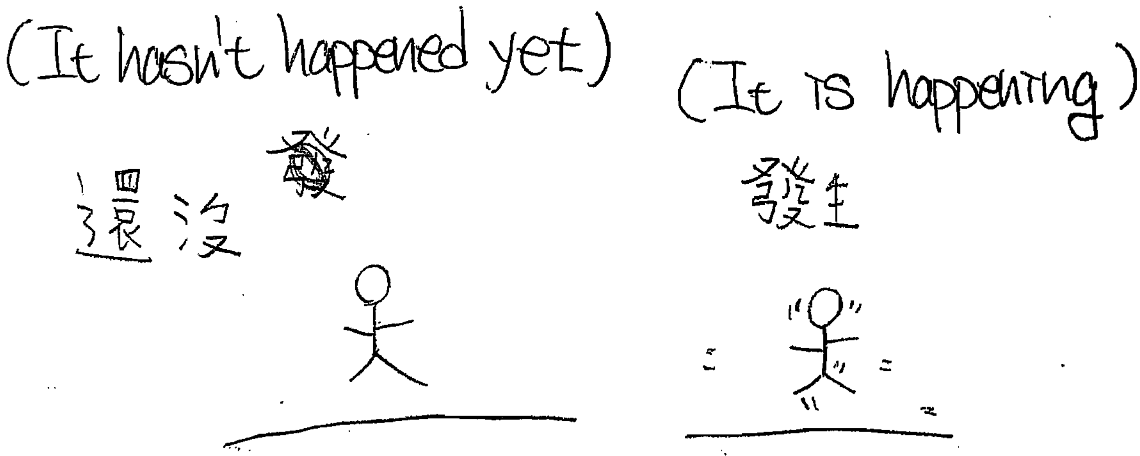
Appendix 15 An Earthquake/Primary Year 3



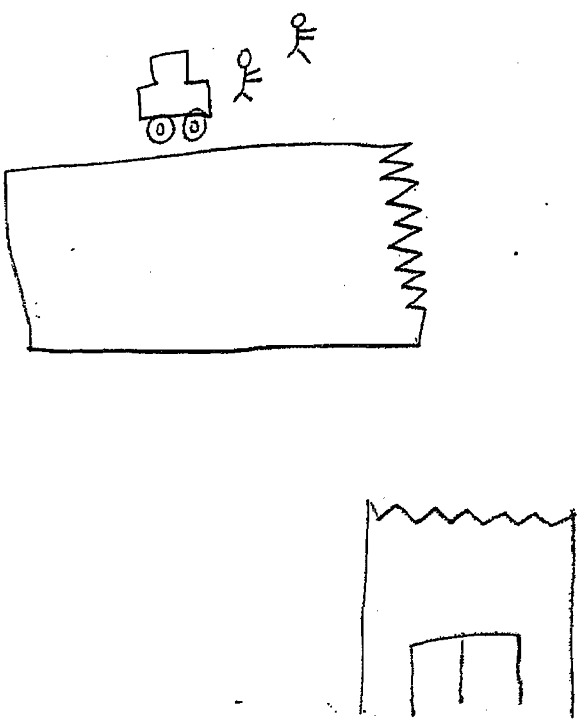
Appendix 16 An Earthquake/Primary Year 3



Appendix 17 An Earthquake/Primary Year 3

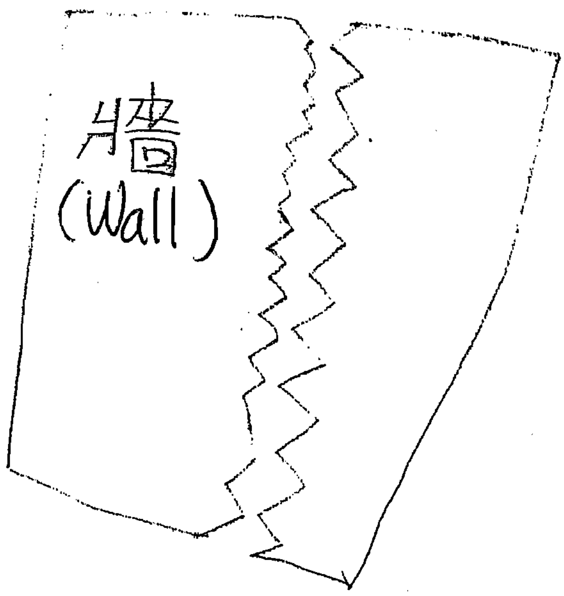


Appendix 18 An Earthquake/Primary Year 3

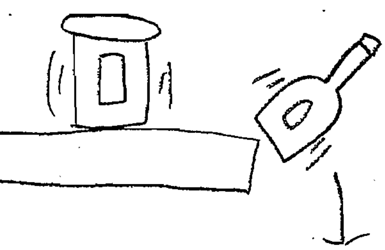


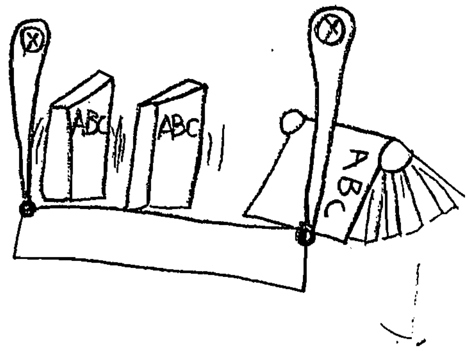
Appendix 19 An Earthquake/Primary Year 3

Appendix 20 An Earthquake/Primary Year 3



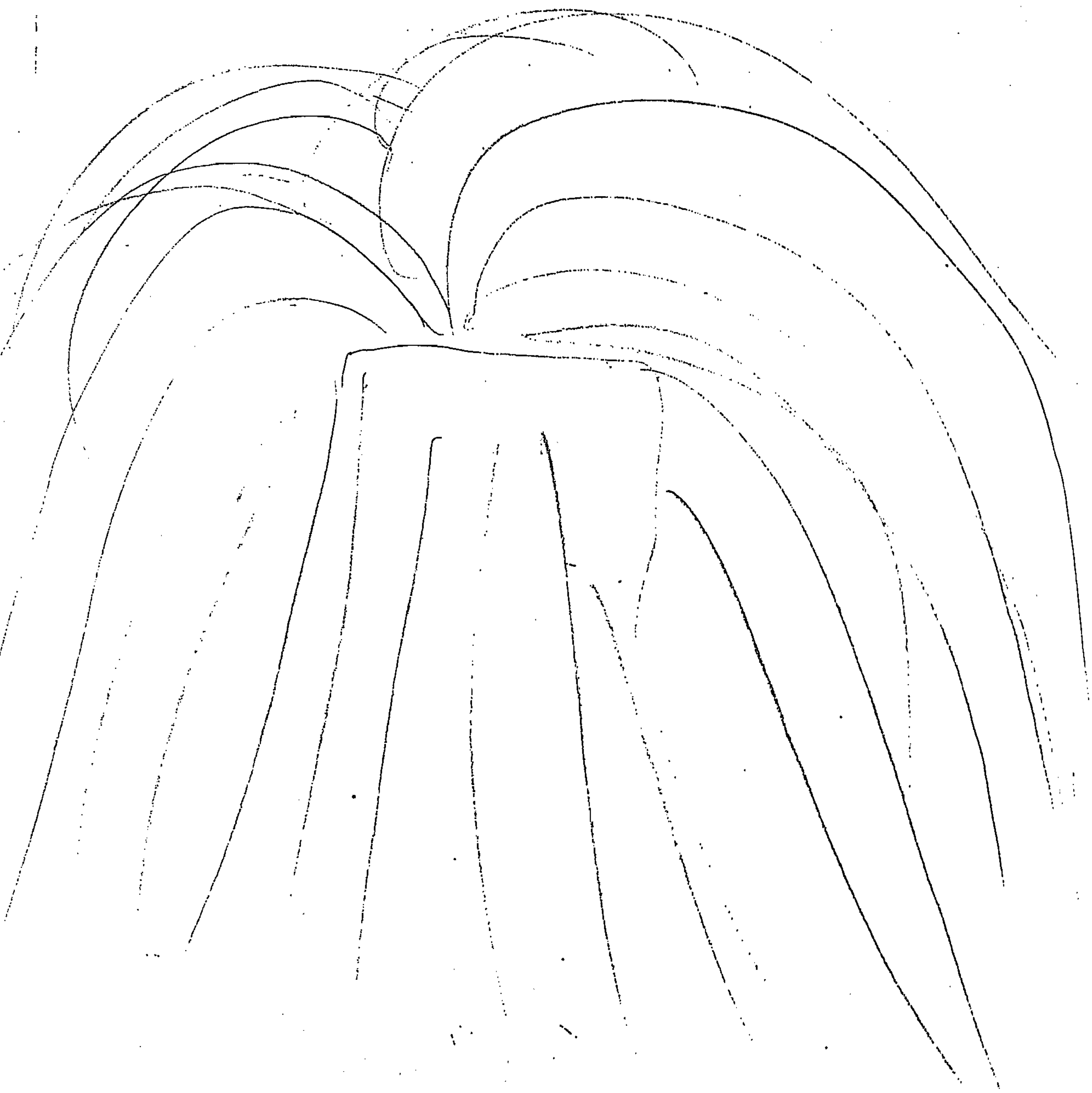
Appendix 21 An Earthquake/Primary Year 3



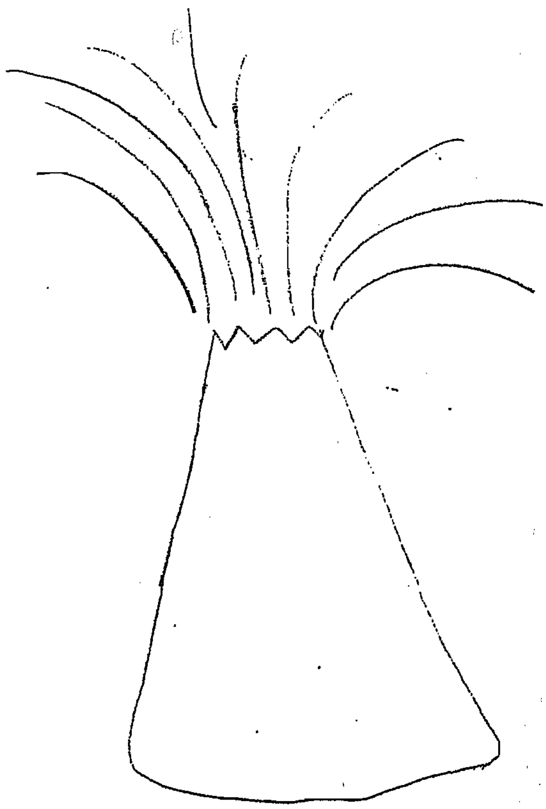


Appendix 22 A Volcano/Primary Year 3

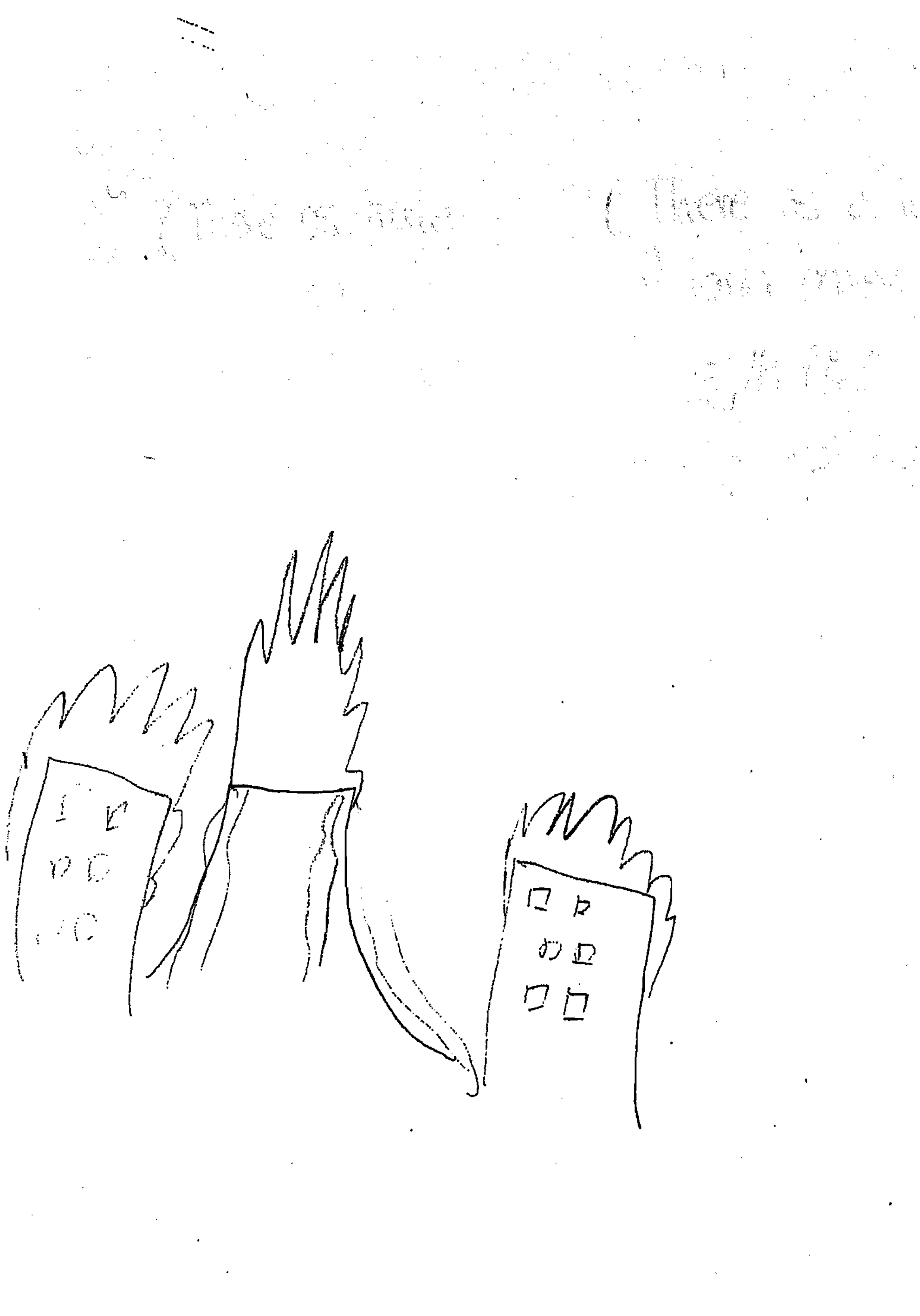
Appendix 23 A Volcano/ Primary Year 3



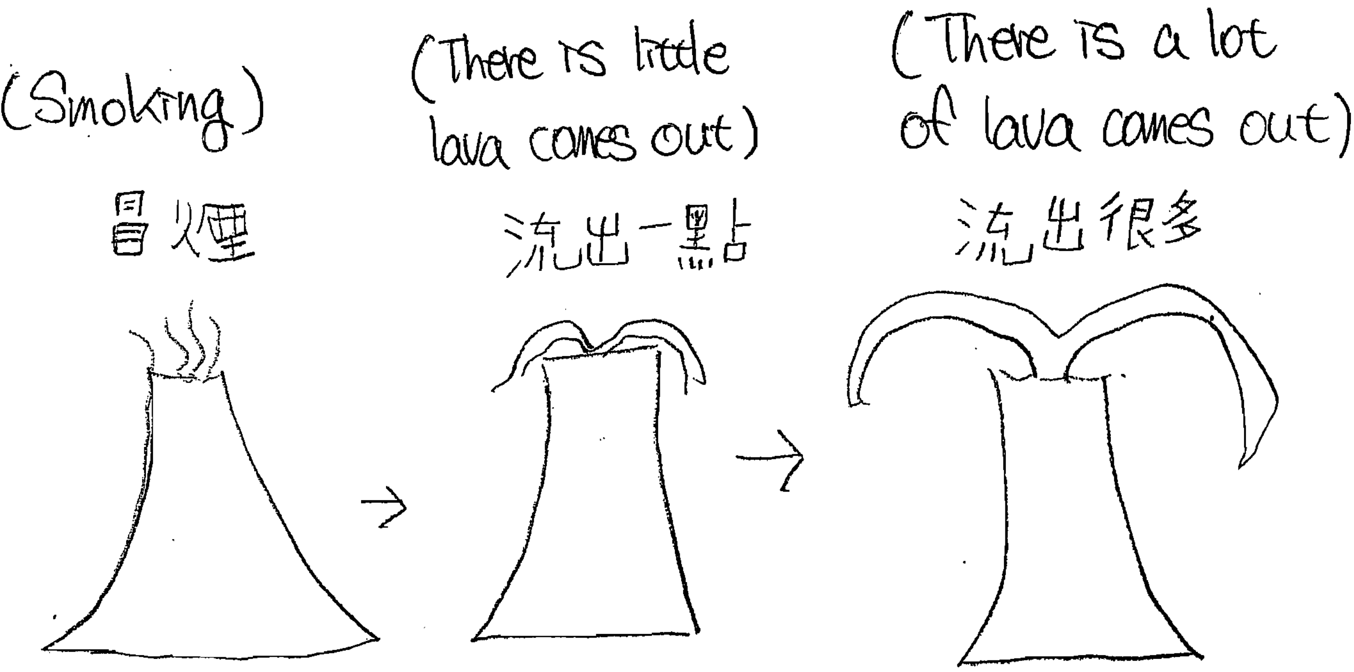
Appendix 24 A Volcano/ Primary Year 3



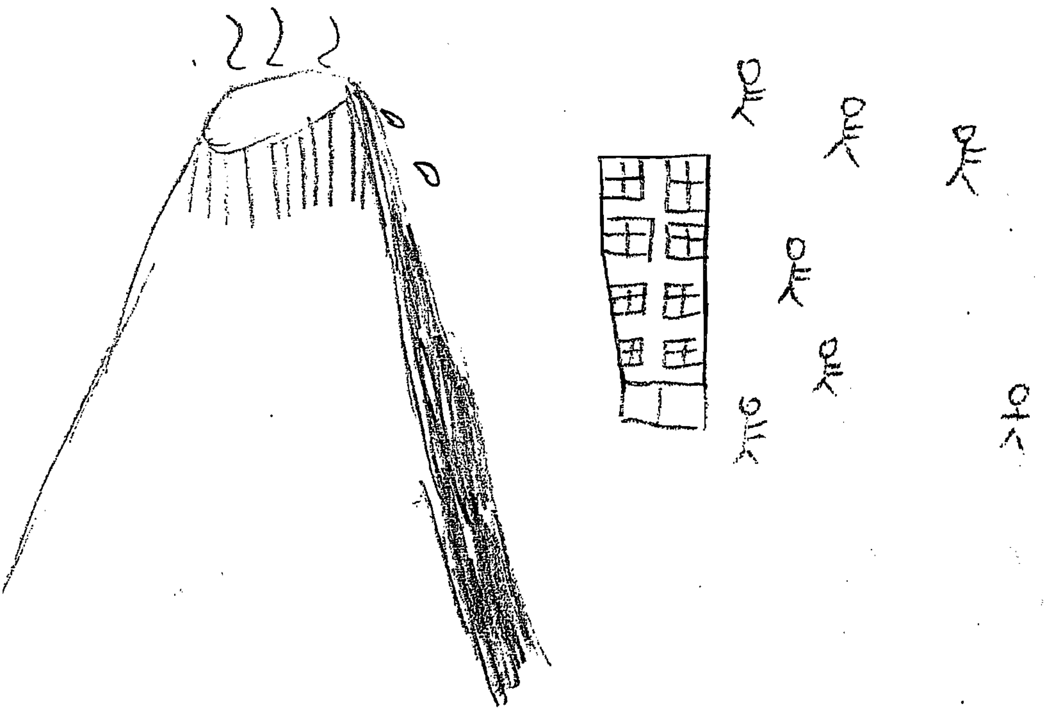
Appendix 25 A Volcano/ Primary Year 3



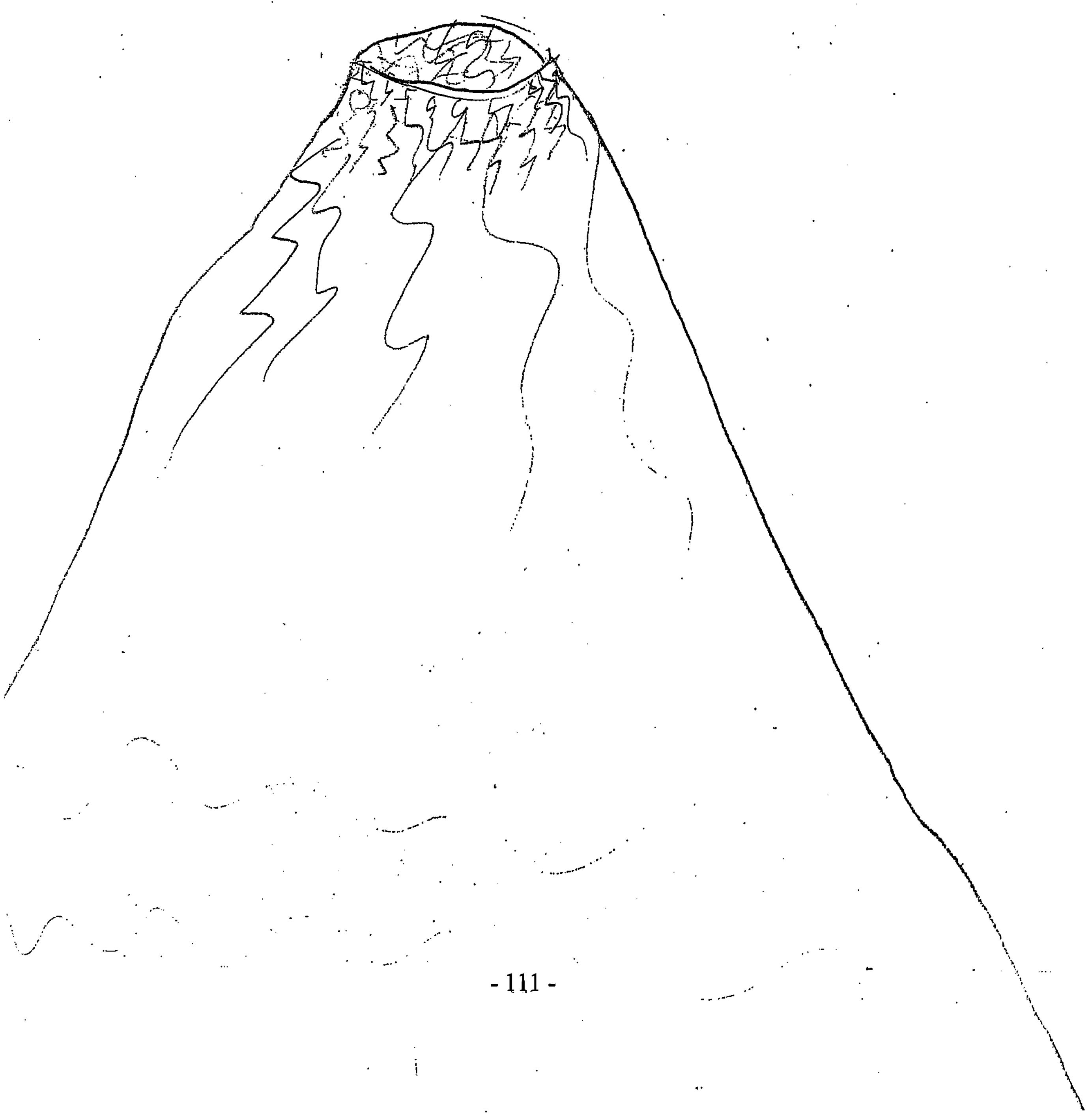
Appendix 26 A Volcano/ Primary Year 3



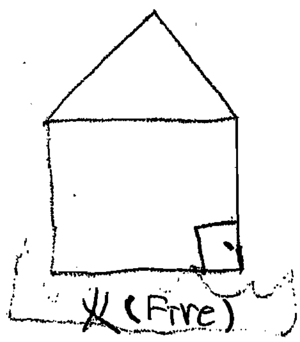
Appendix 27 A Volcano/ Primary Year 3



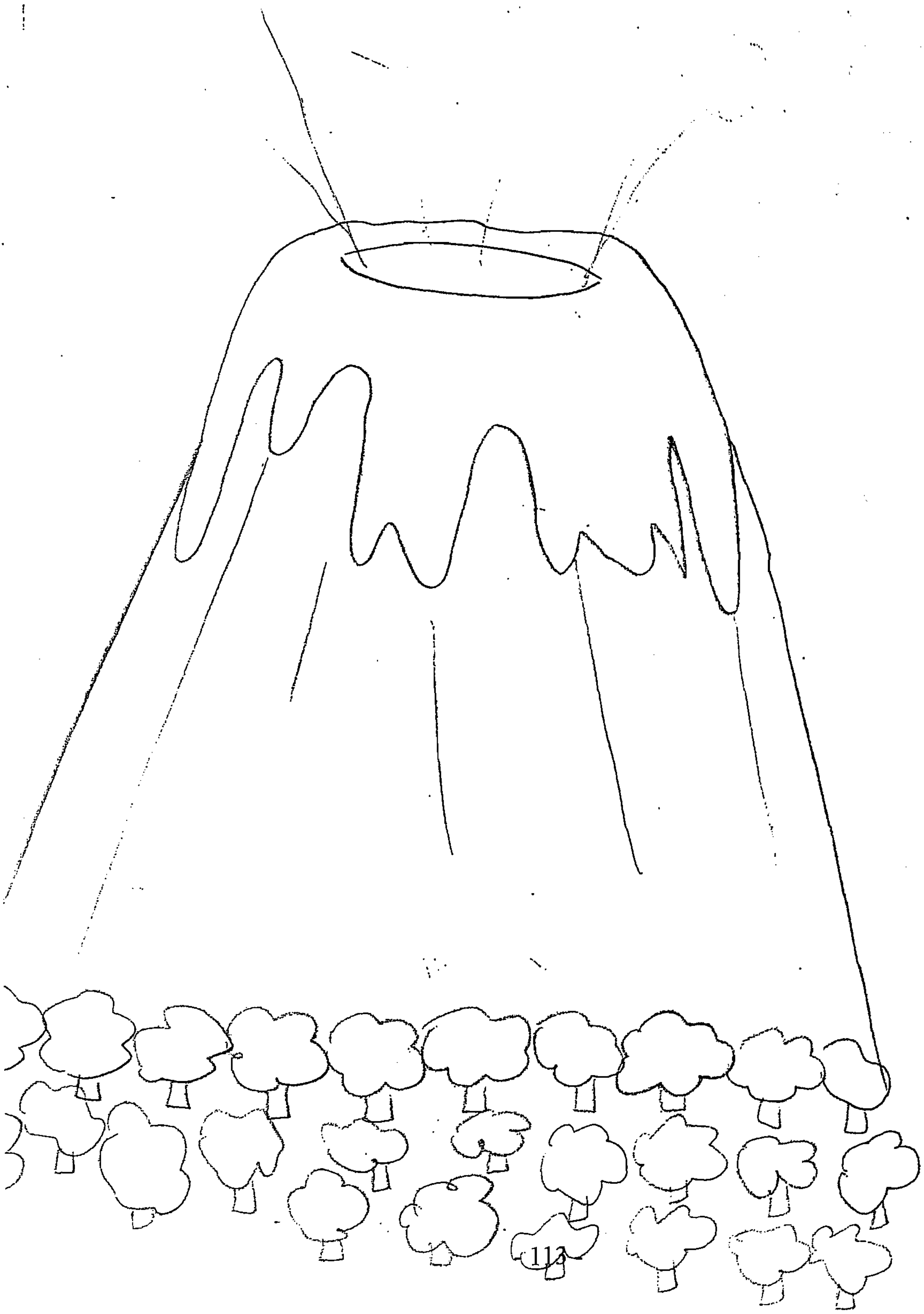
Appendix 28 A Volcano/ Primary Year 3



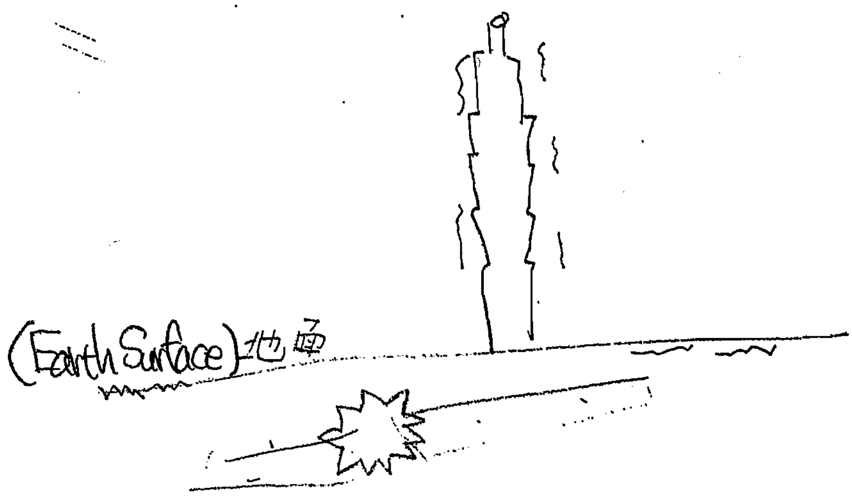
Appendix 29 A Volcano/ Primary Year 3



Appendix 30 A Volcano/ Primary Year 3

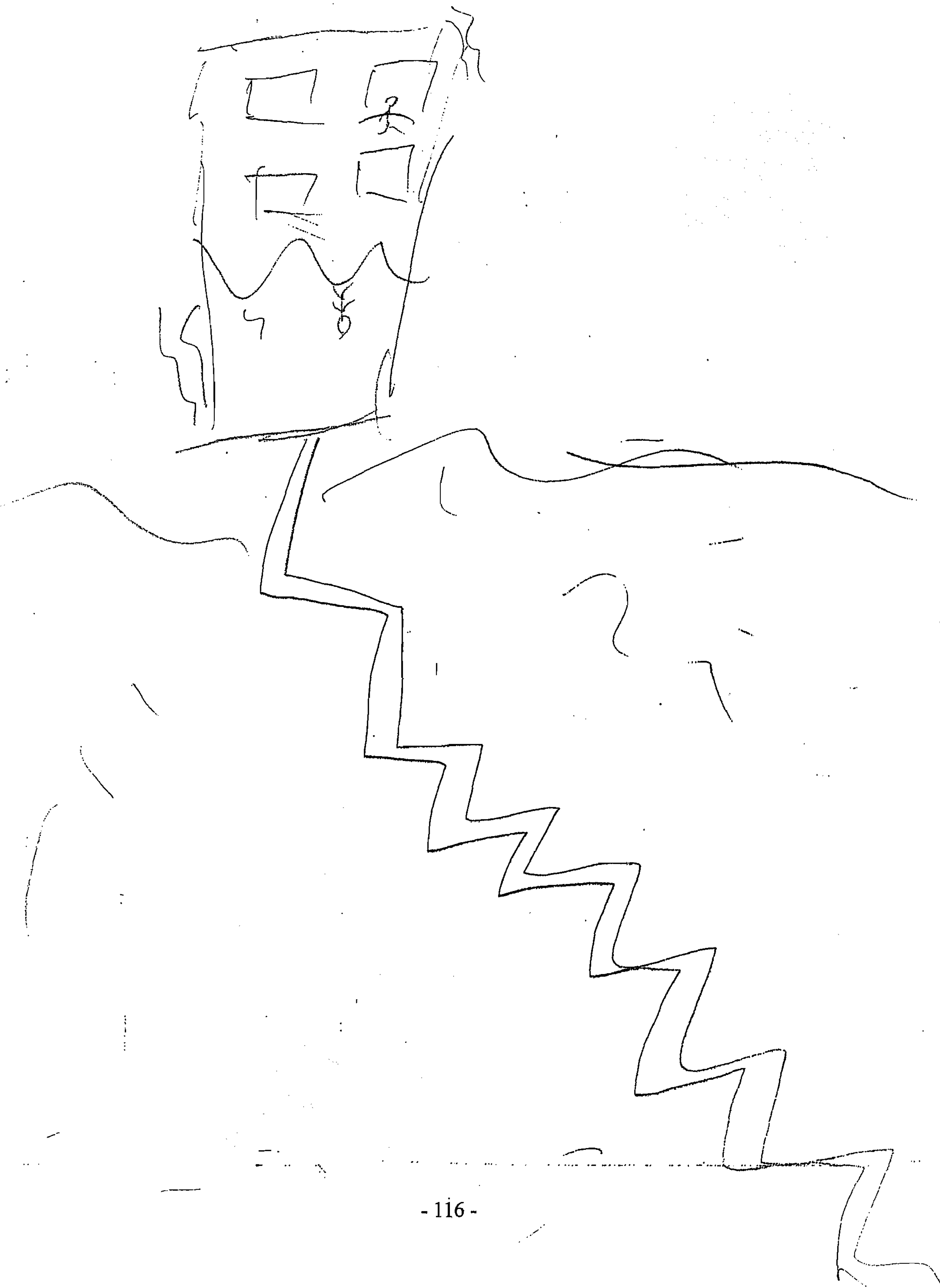


Appendix 31 An Earthquake/Primary Year 6



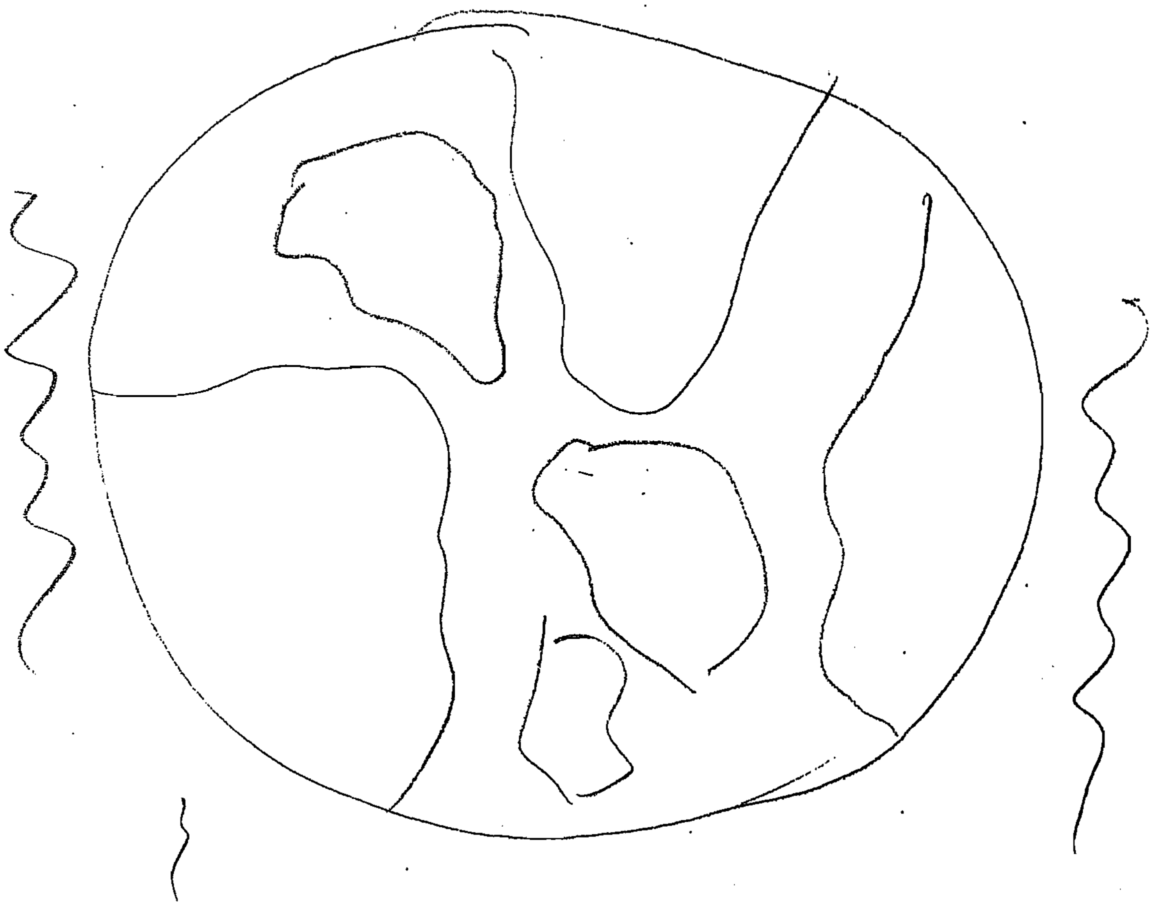
Appendix 32 An Earthquake/Primary Year 6

Appendix 33 An Earthquake/Primary Year 6

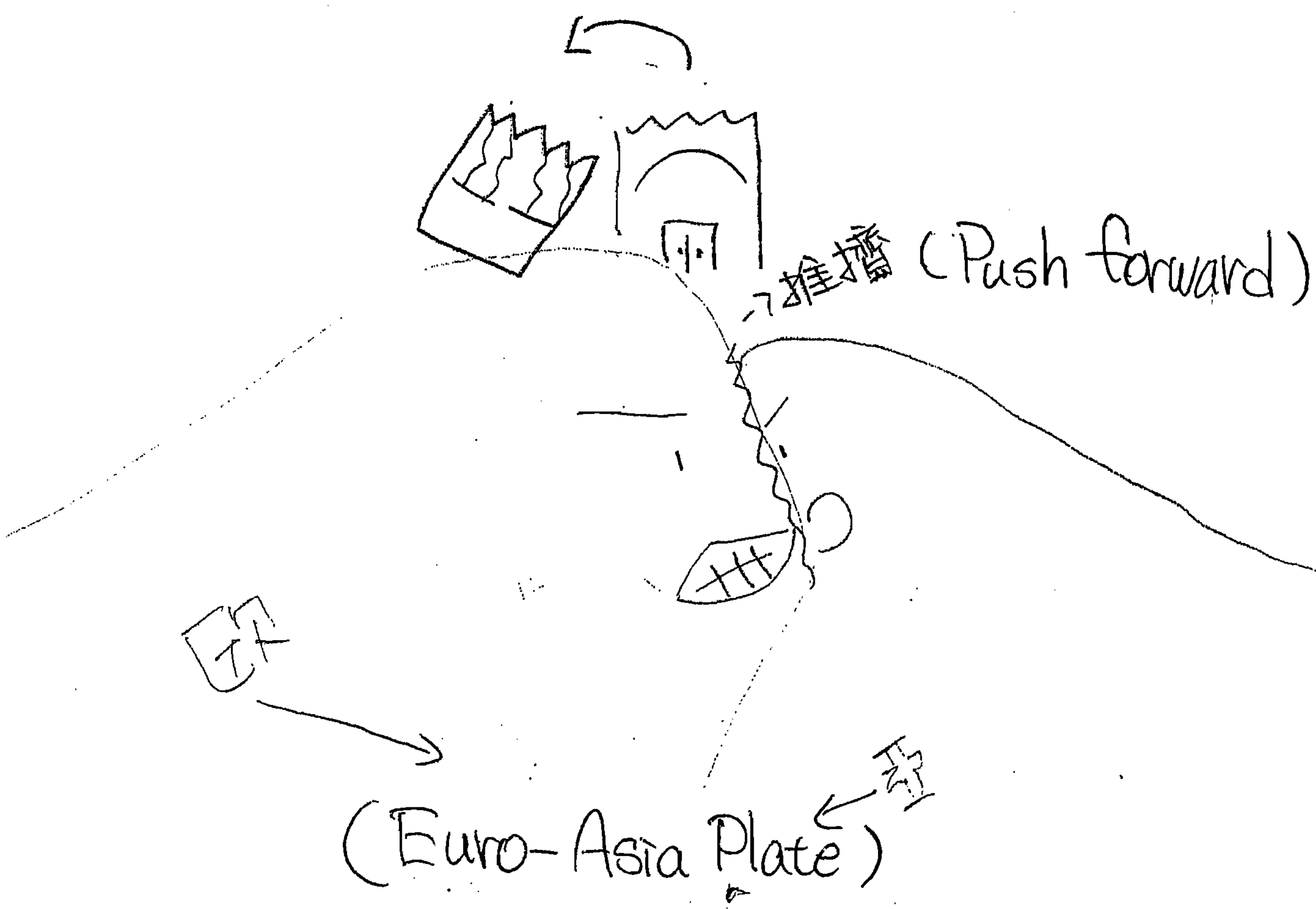


Appendix 34 An Earthquake/Primary Year 6

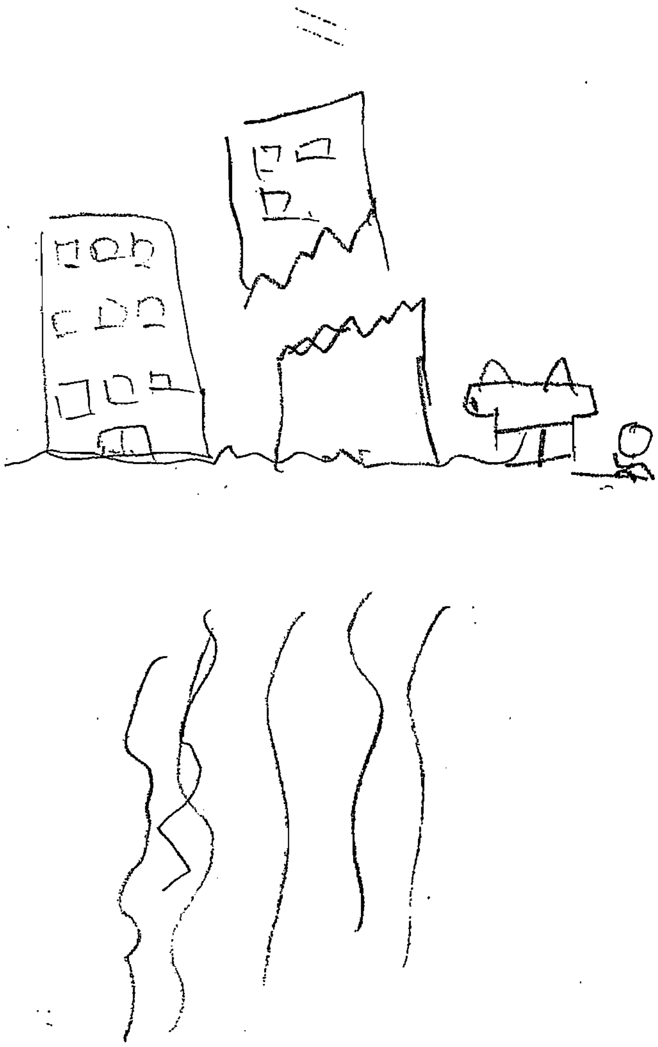
Appendix 35 An Earthquake/Primary Year 6



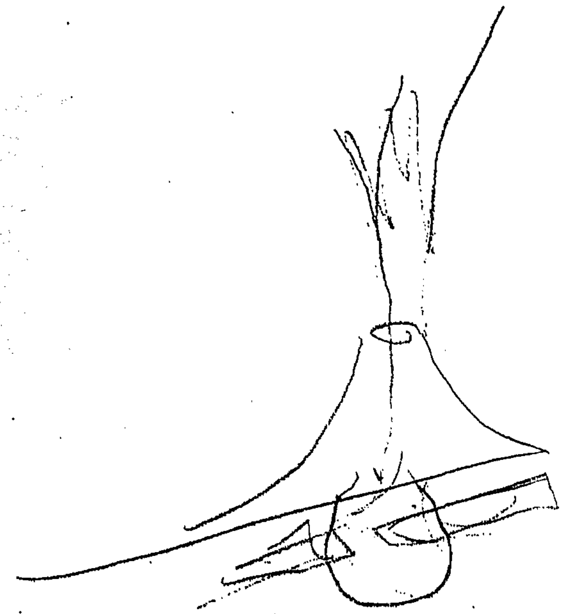
Appendix 36 An Earthquake/Primary Year 6



Appendix 37 An Earthquake/Primary Year 6

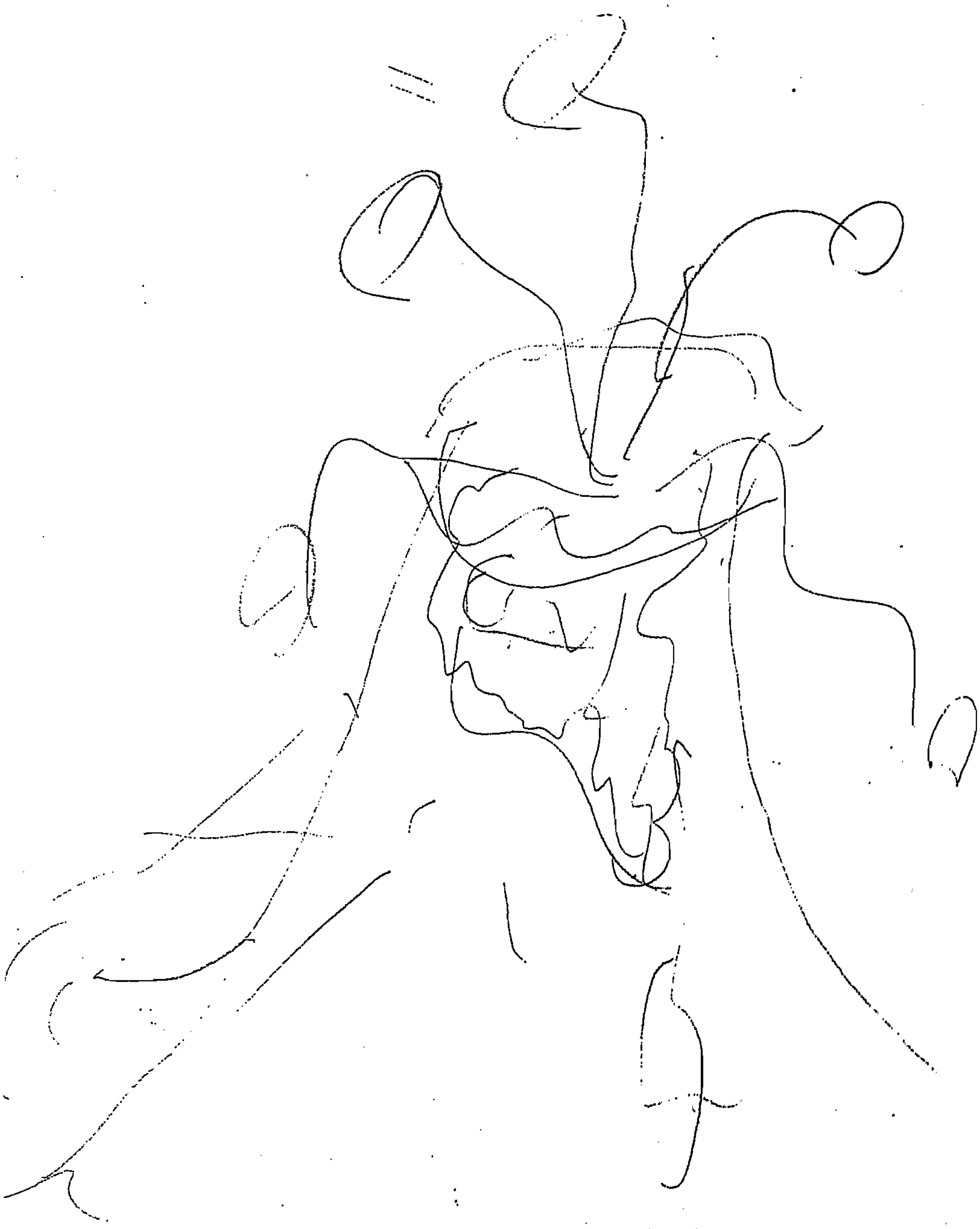


Appendix 38 A Volcano/Primary Year 6

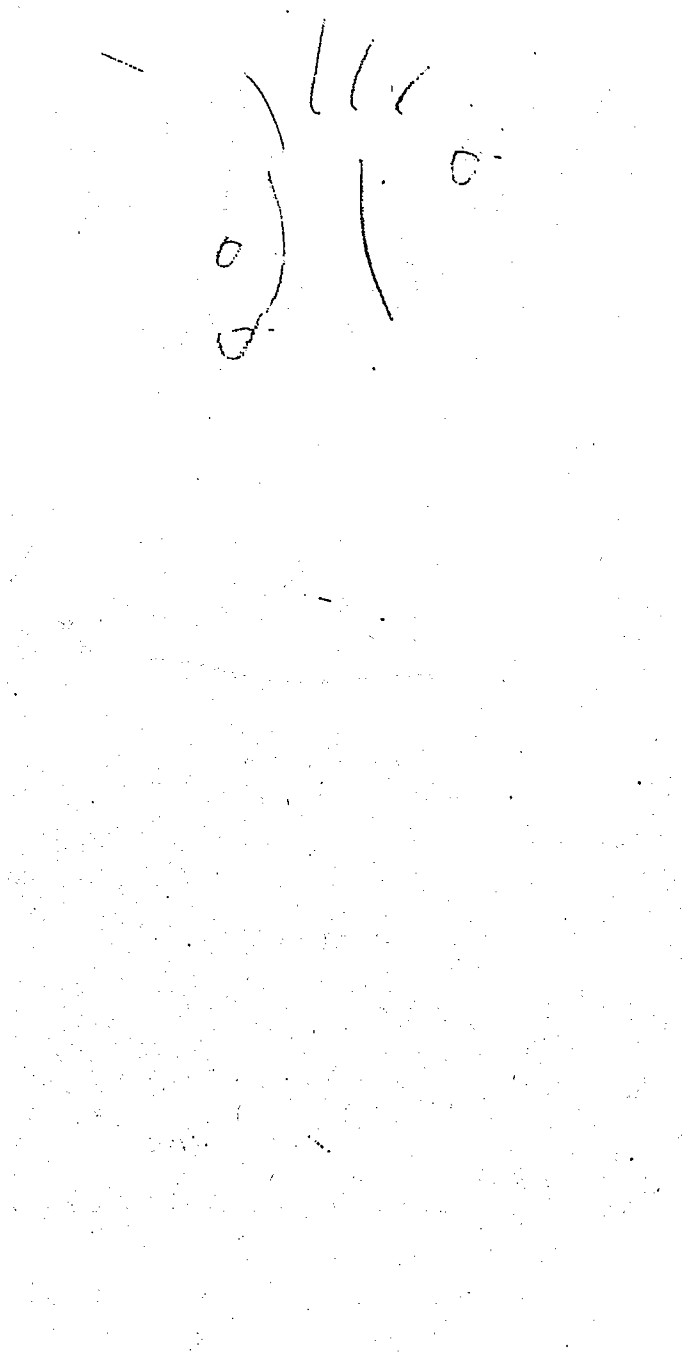


Appendix 39 A Volcano/Primary Year 6

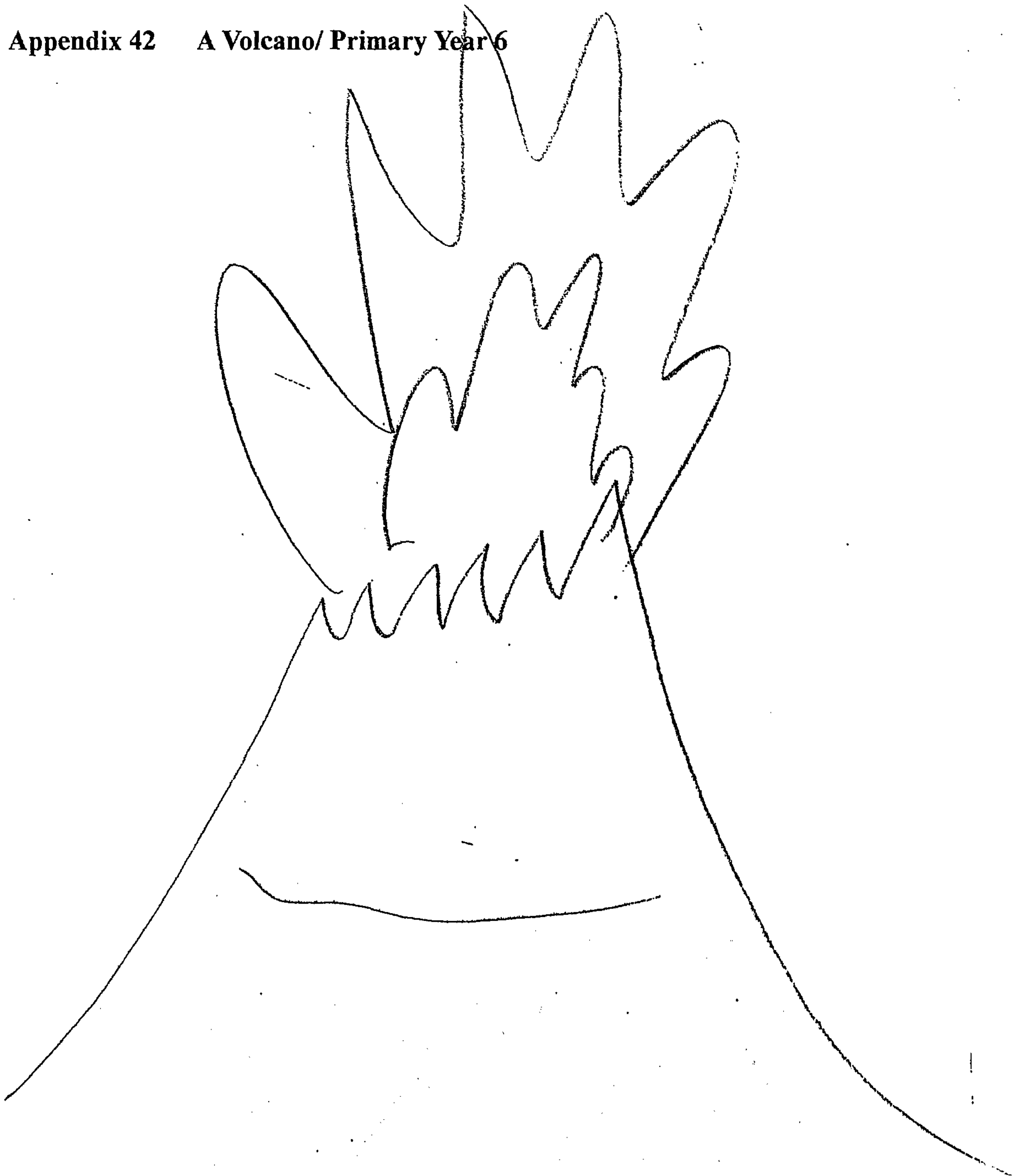
Appendix 40 A Volcano/ Primary Year 6



Appendix 41 A Volcano/ Primary Year 6



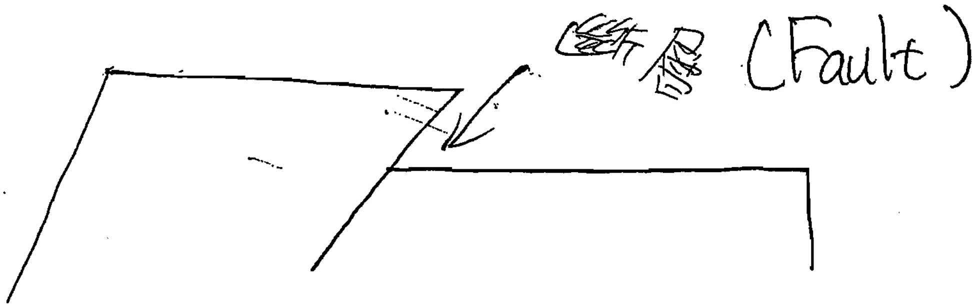
Appendix 42 A Volcano/ Primary Year 6



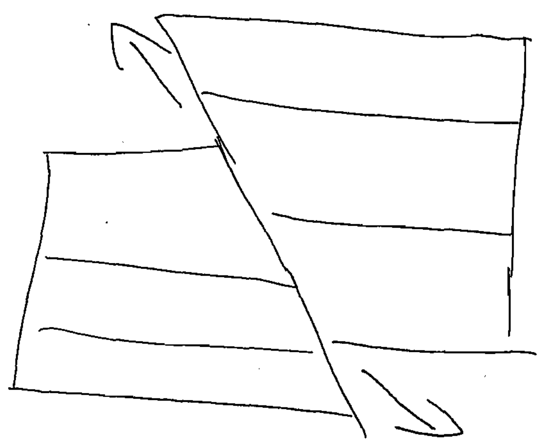
Appendix 43 A Volcano/ Primary Year 6

Appendix 44 A Volcano/ Primary Year 6

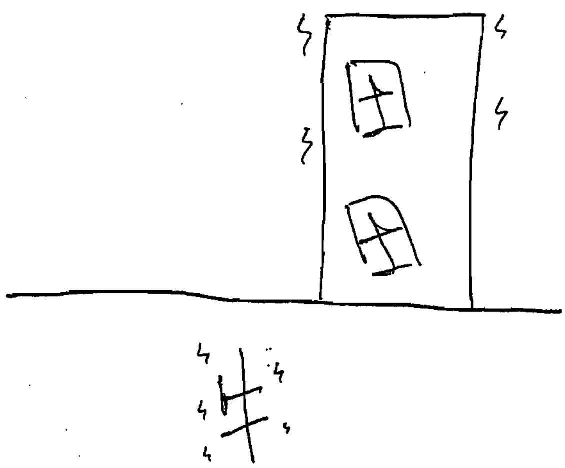
Appendix 45 An Earthquake/Junior High School Year 3



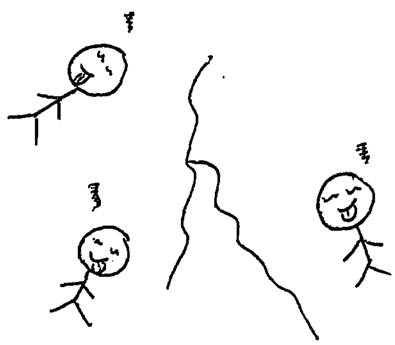
Appendix 46 An Earthquake/ Junior High School Year 3



Appendix 47 An Earthquake/ Junior High School Year 3



Appendix 48 An Earthquake/ Junior High School Year 3



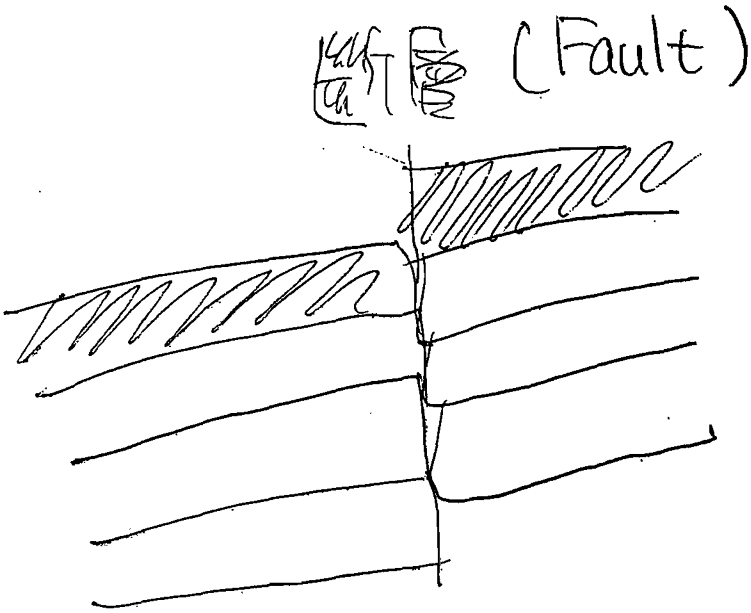
(The earth stretches out; It is an earthquake)

因為地裂開…是代表地震

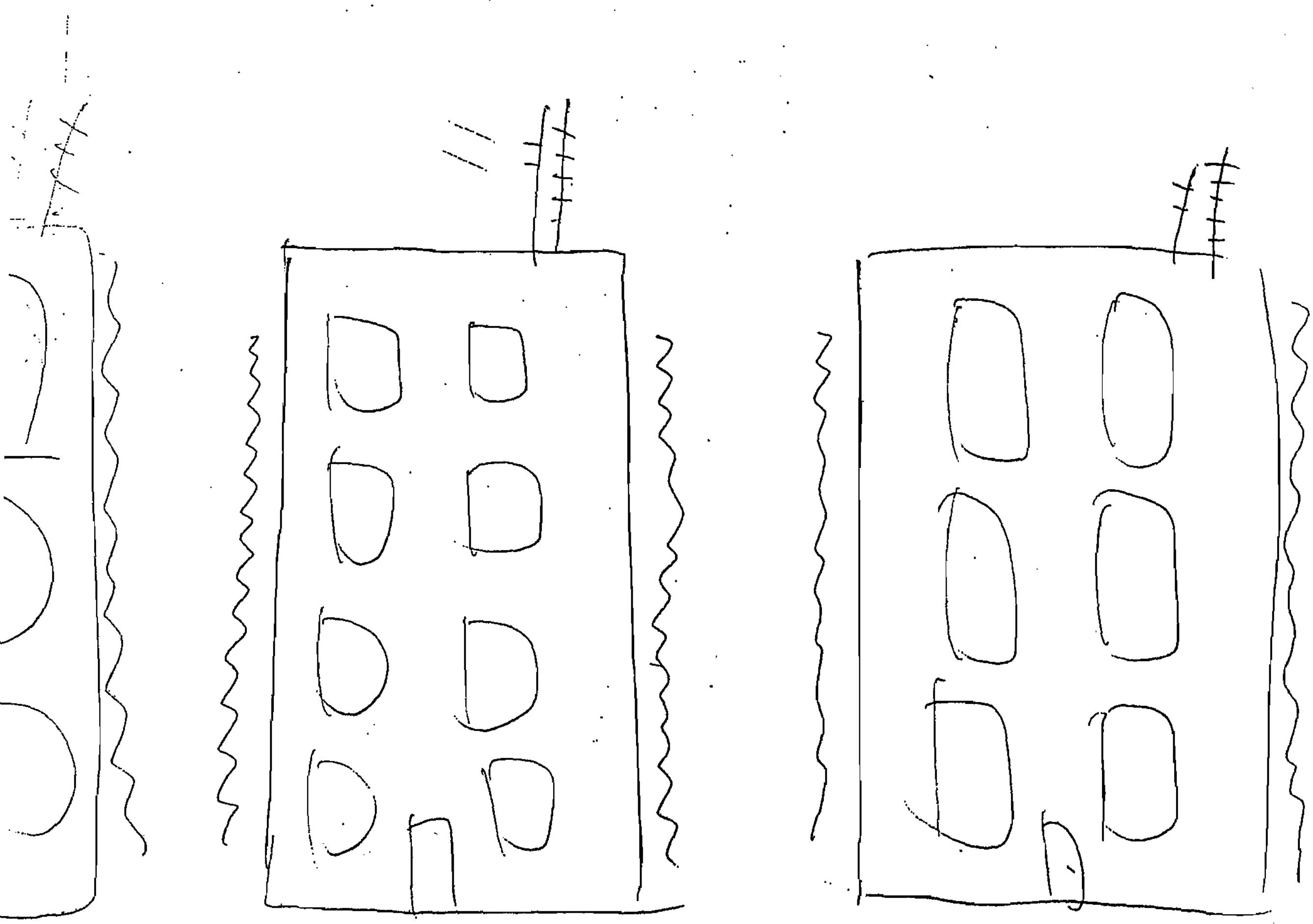
人死掉…代表災害…

(Casualties mean that they are hazards)

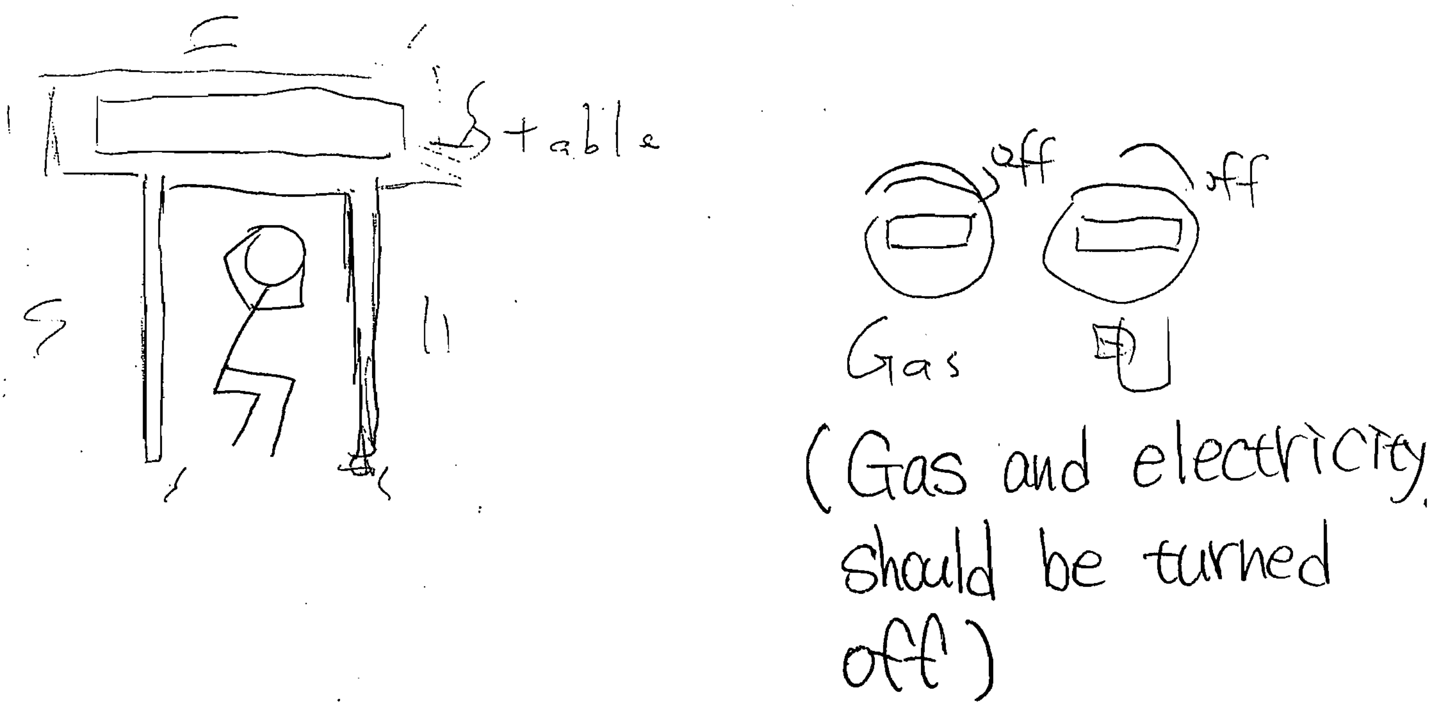
Appendix 49 An Earthquake/ Junior High School Year 3



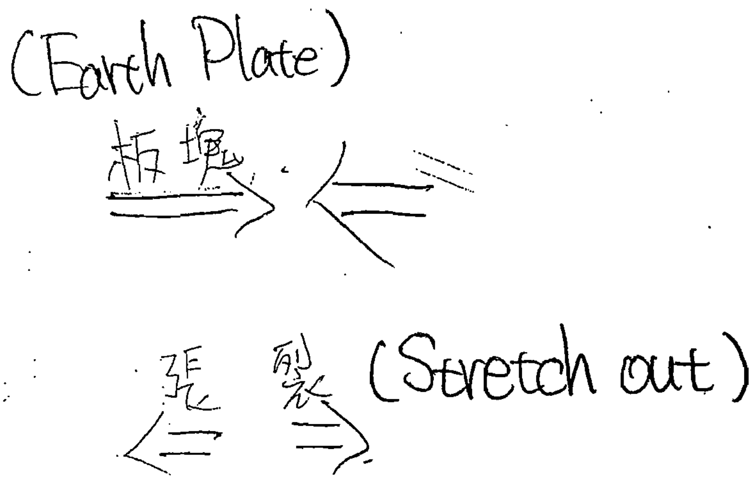
Appendix 50 An Earthquake/ Junior High School Year 3



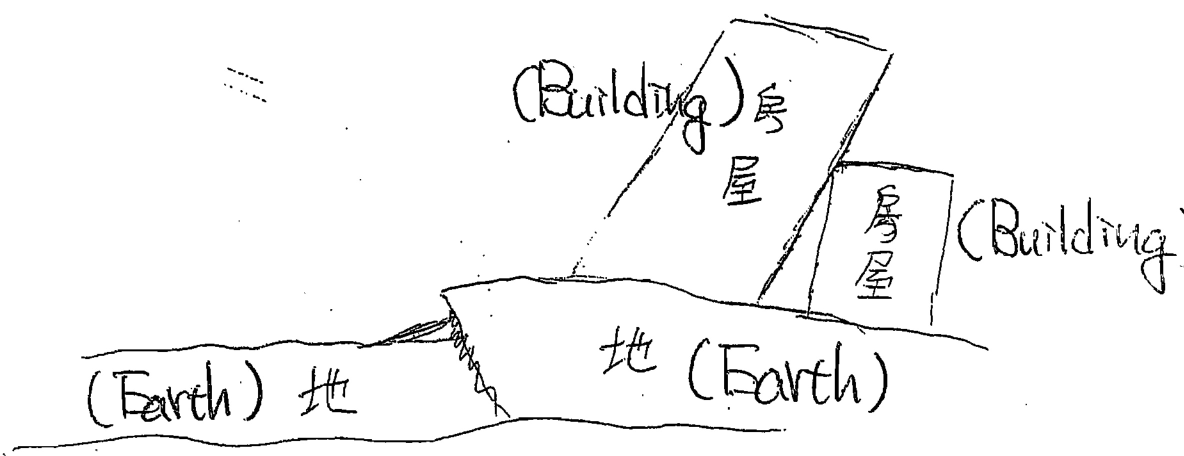
Appendix 51 An Earthquake/ Junior High School Year 3



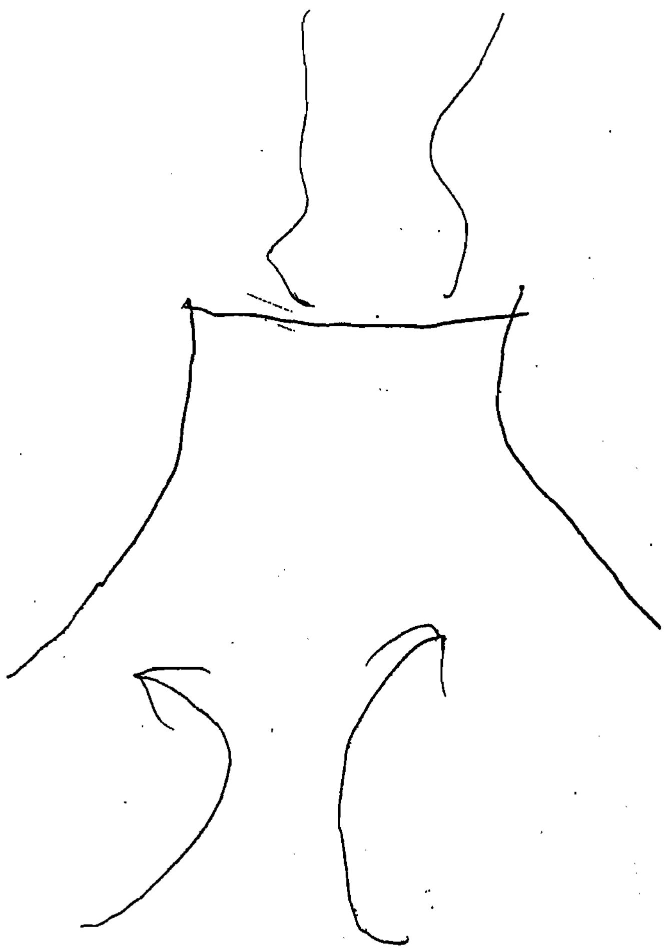
Appendix 52 An Earthquake/ Junior High School Year 3



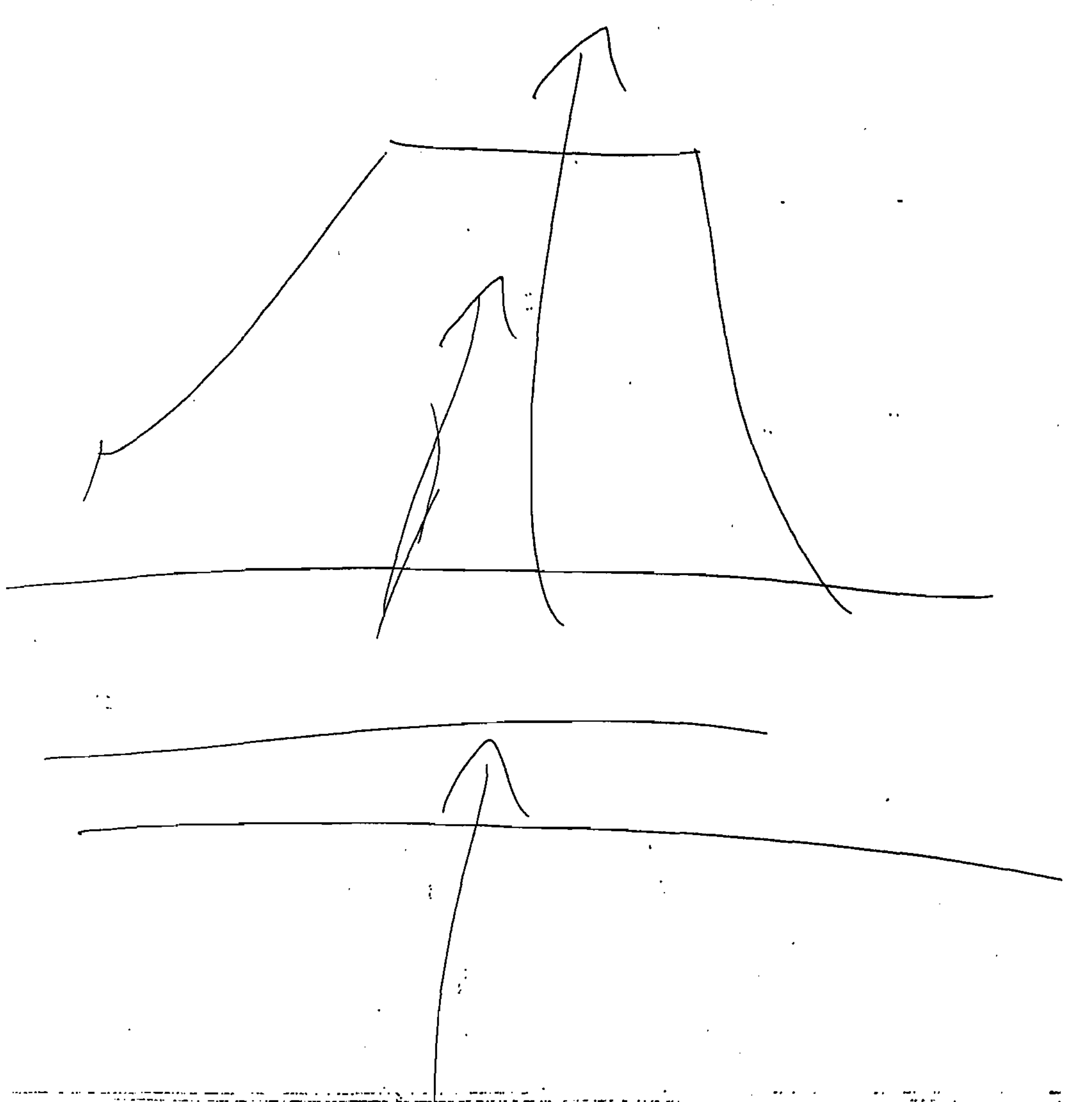
Appendix 53 An Earthquake/ Junior High School Year 3



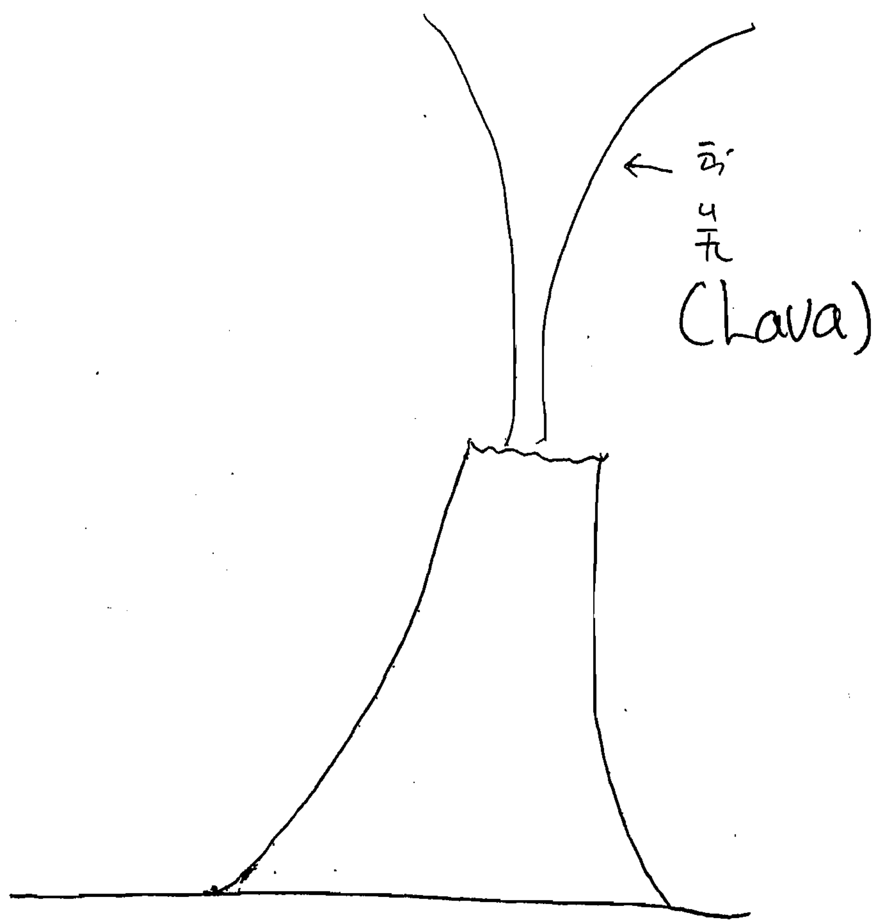
Appendix 54   A Volcano/Junior High School Year 3



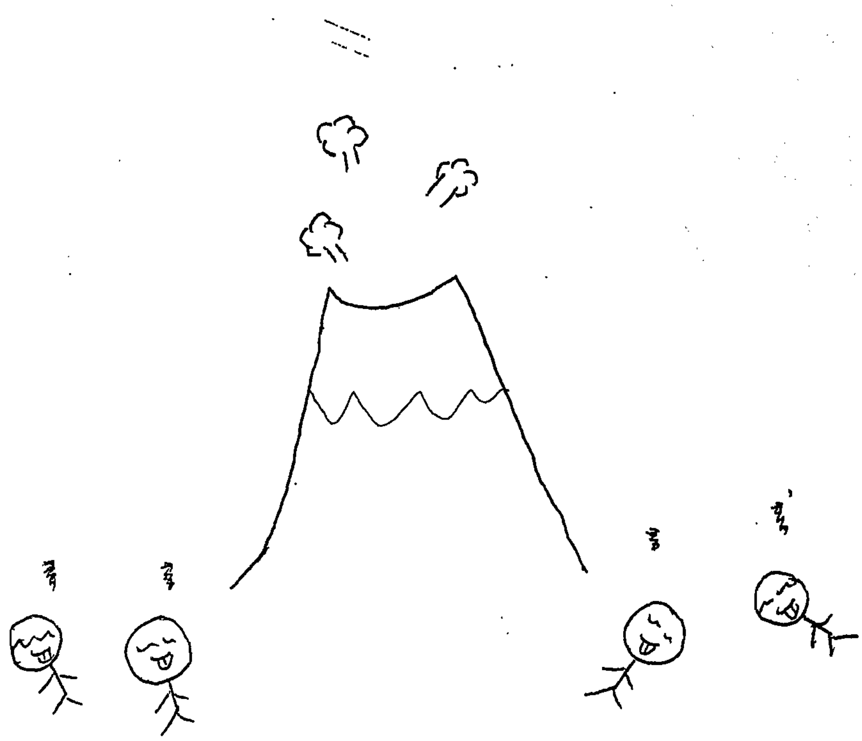
Appendix 55 A Volcano/ Junior High School Year 3



Appendix 56 A Volcano/ Junior High School Year 3



Appendix 57 A Volcano/ Junior High School Year 3



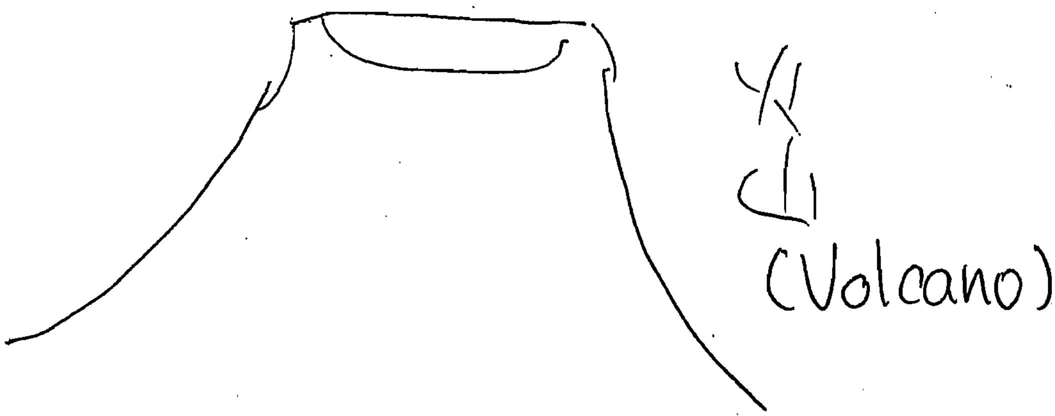
(A mountain with spitting is a volcano)

山在噴氣代表火山 ...

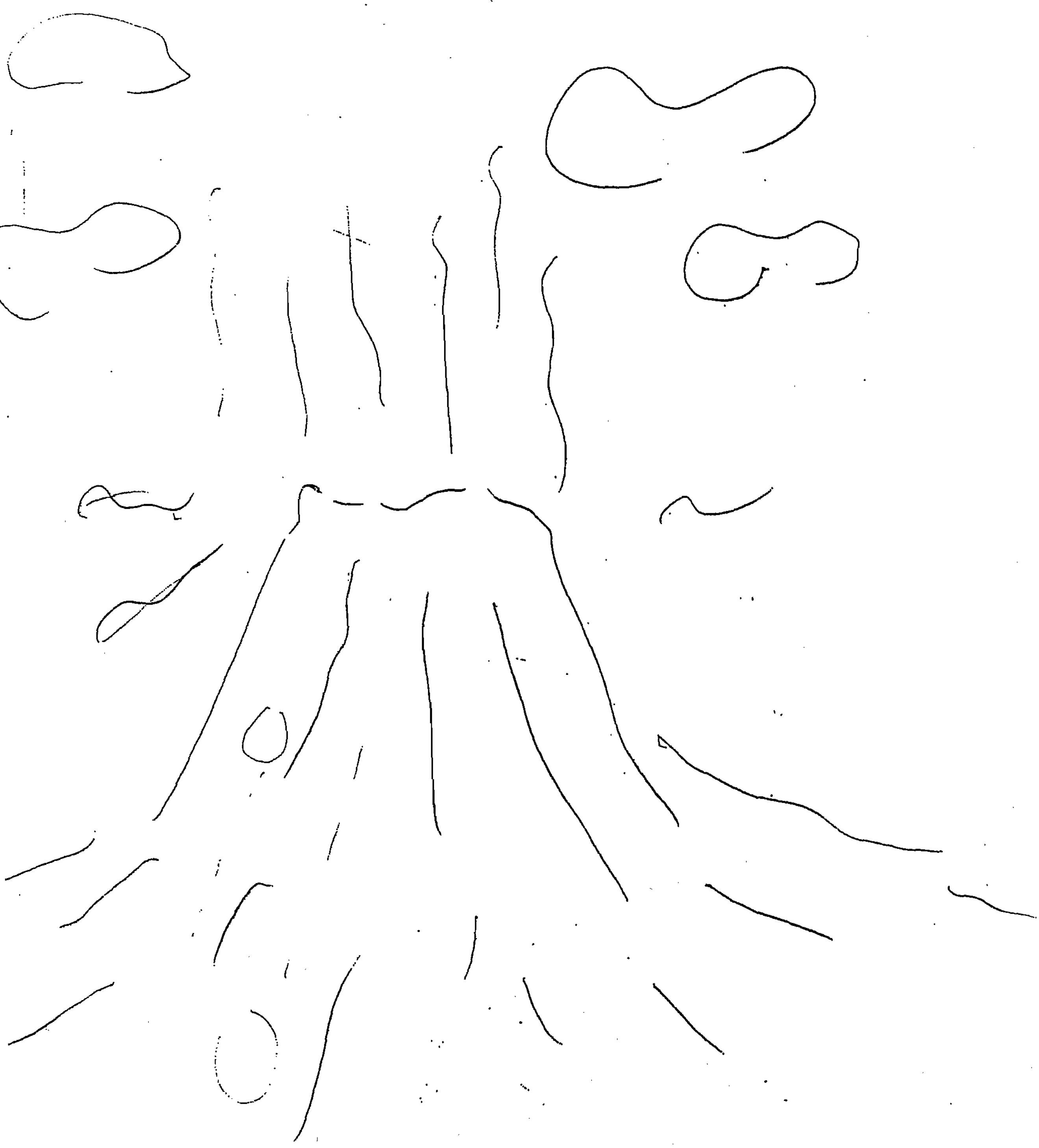
人死掉代表災害 ...

(Casualties mean that they are hazards)

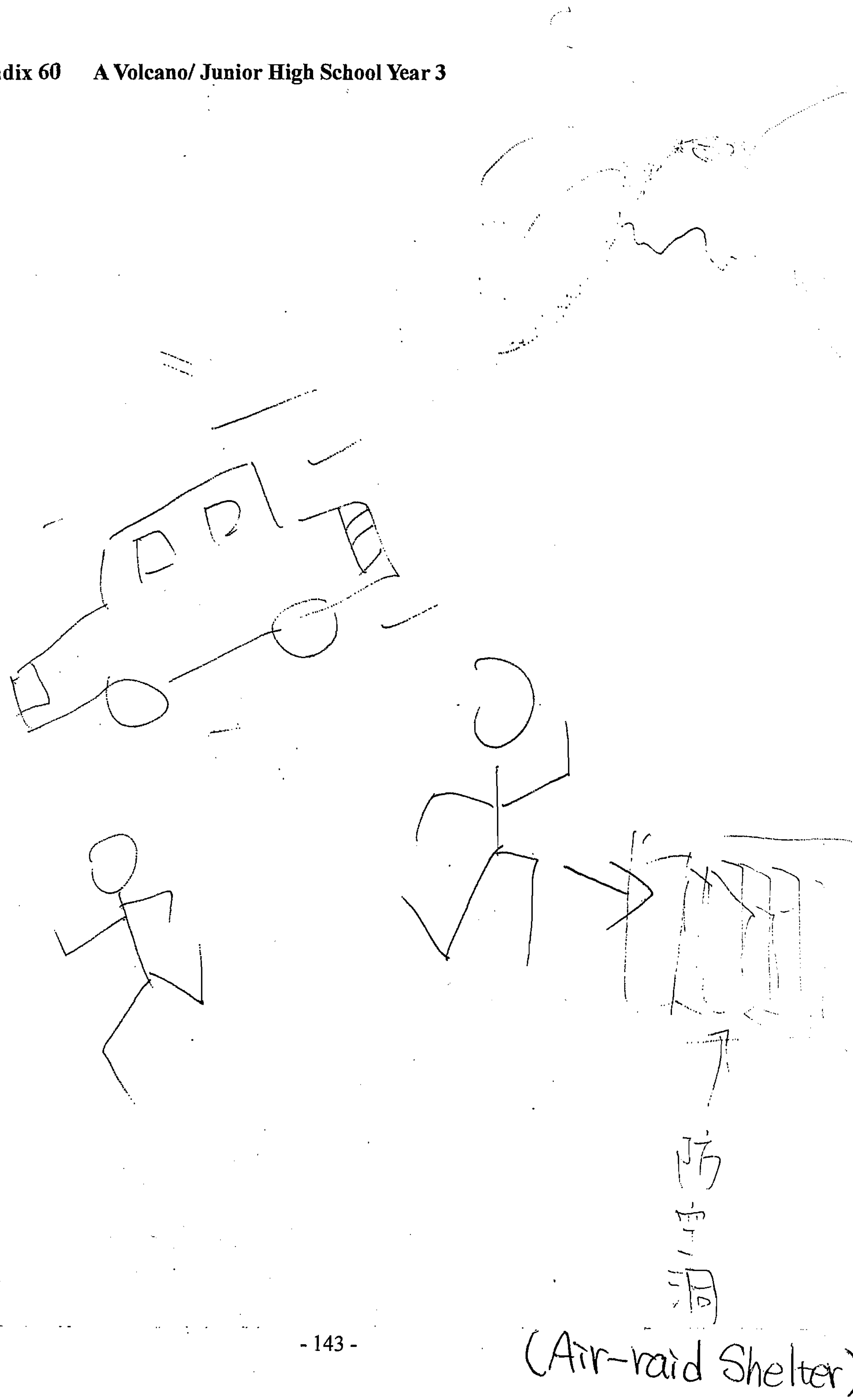
Appendix 58 A Volcano/ junior High School Year 3



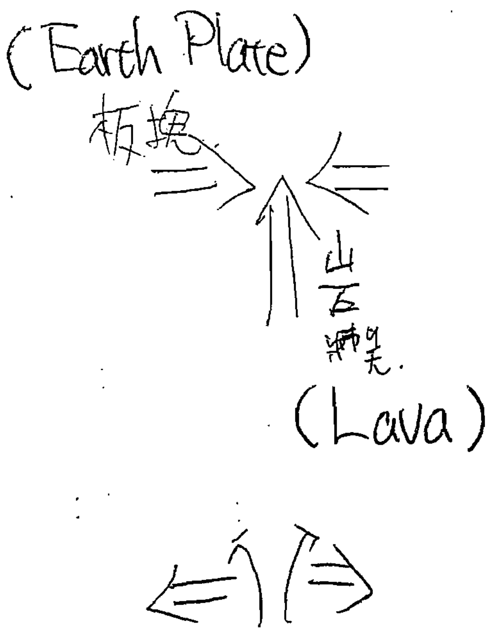
Appendix 59 A Volcano/ Junior High School Year 3



Appendix 60 A Volcano/ Junior High School Year 3

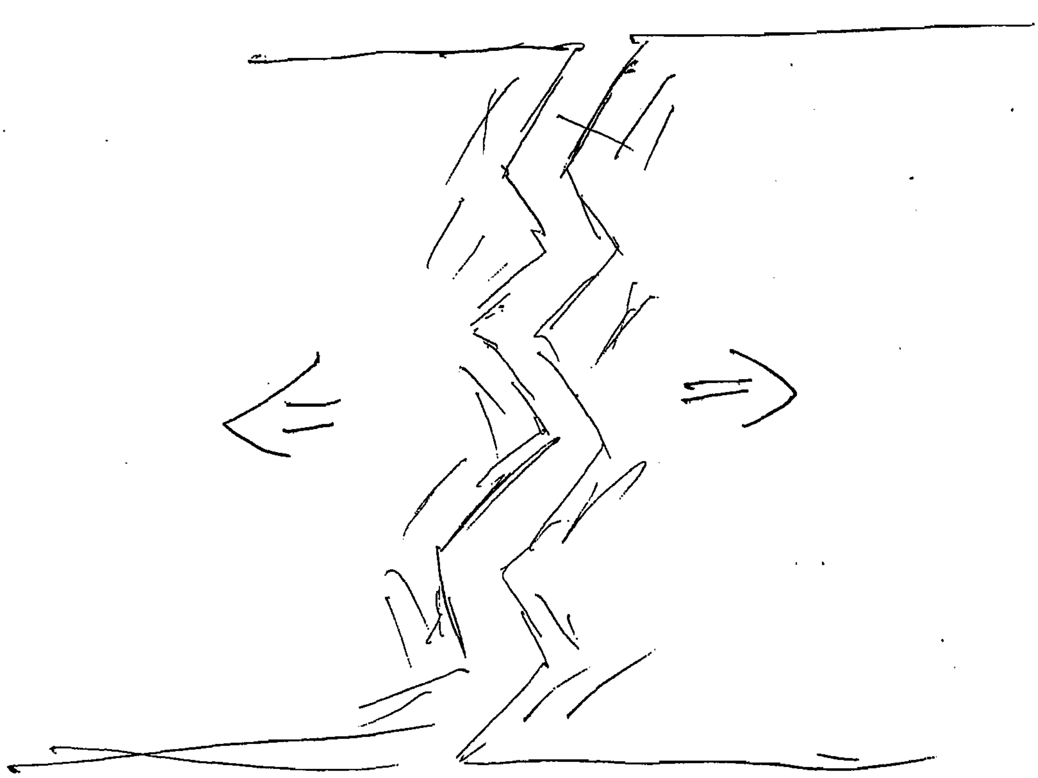


Appendix 61 A Volcano/ Junior High School Year 3

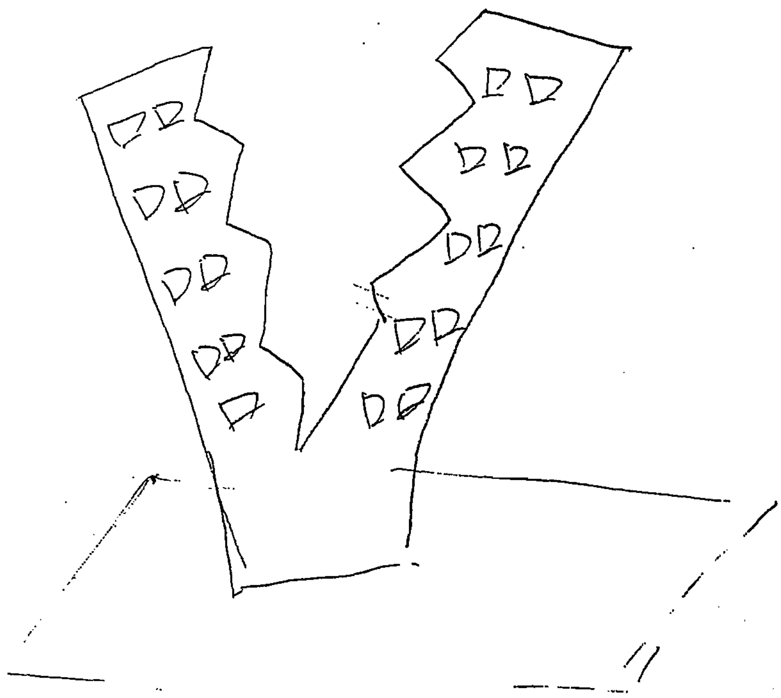


Appendix 62 A Volcano/ Junior High School Year 3

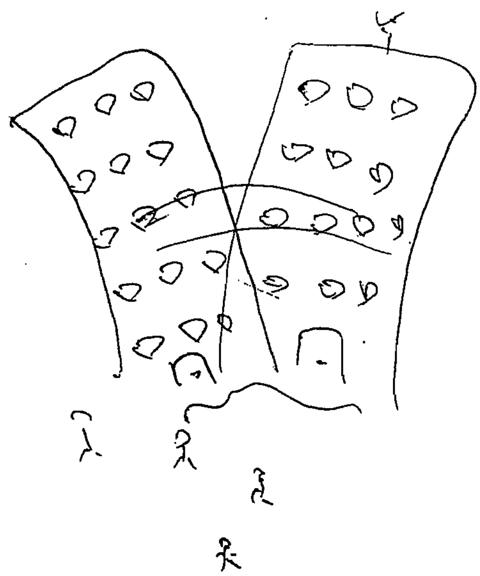
Appendix 63 An Earthquake/Senior High School Year 3



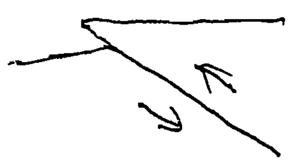
Appendix 64 An Earthquake/ Senior High School Year 3



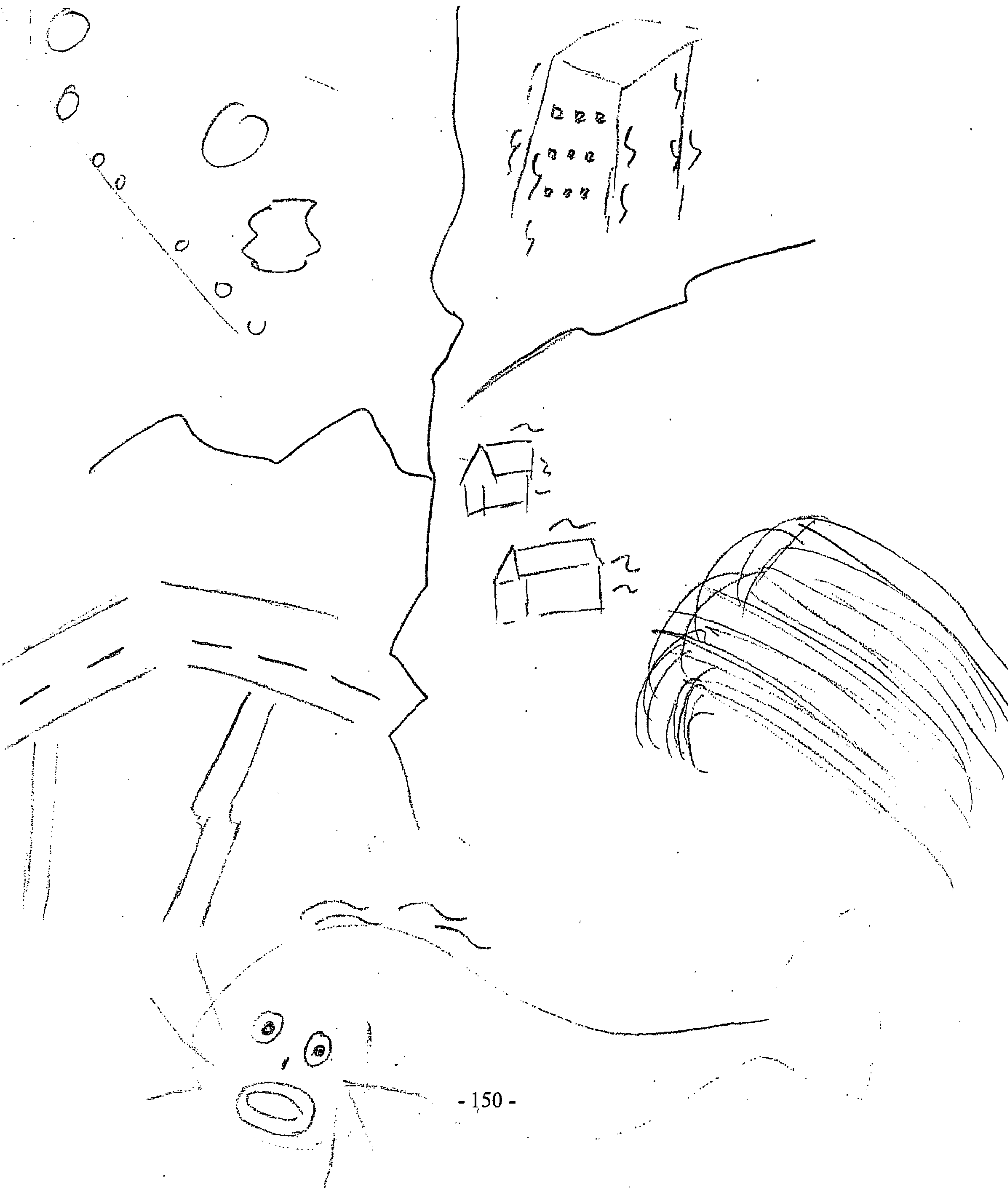
Appendix 65 An Earthquake/ Senior High School Year 3



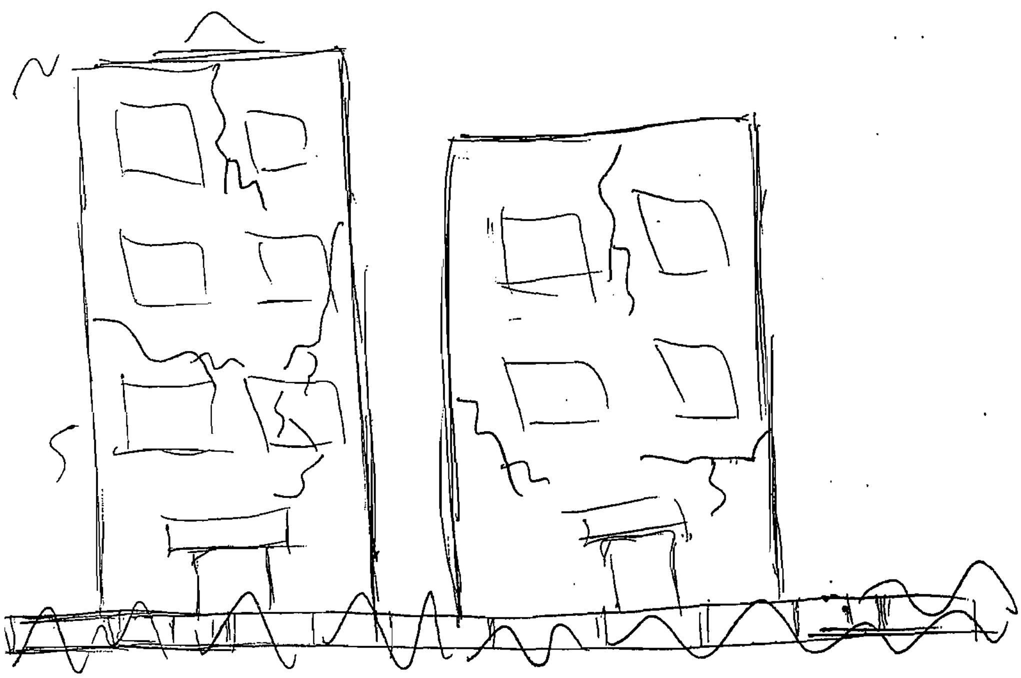
Appendix 66 An Earthquake/ Senior High School Year 3



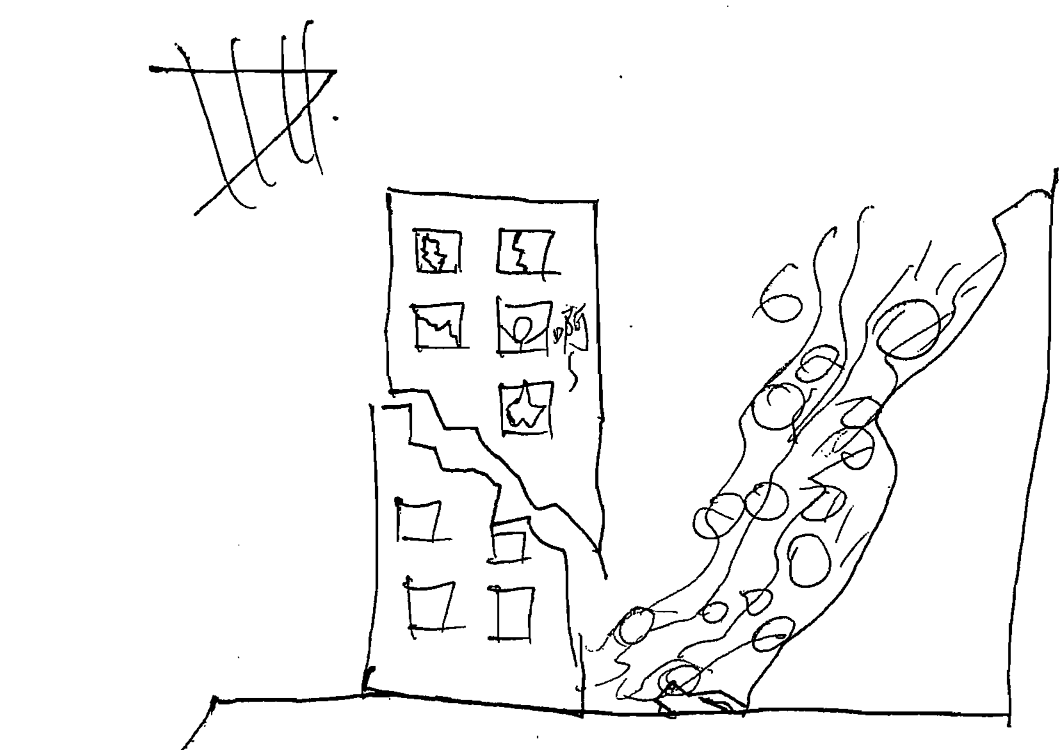
Appendix 67 An Earthquake/ Senior High School Year 3



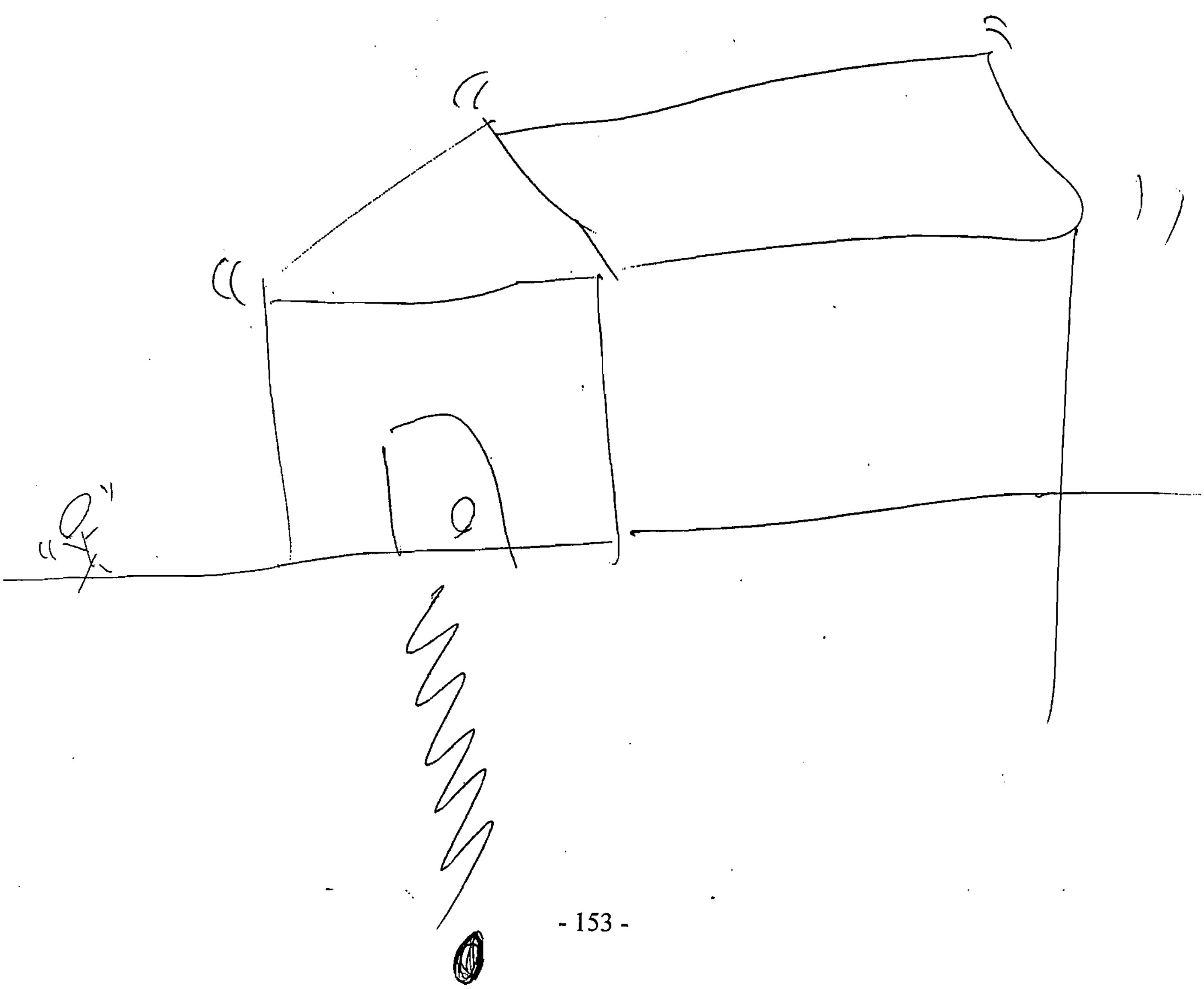
Appendix 68 An Earthquake/ Senior High School Year 3



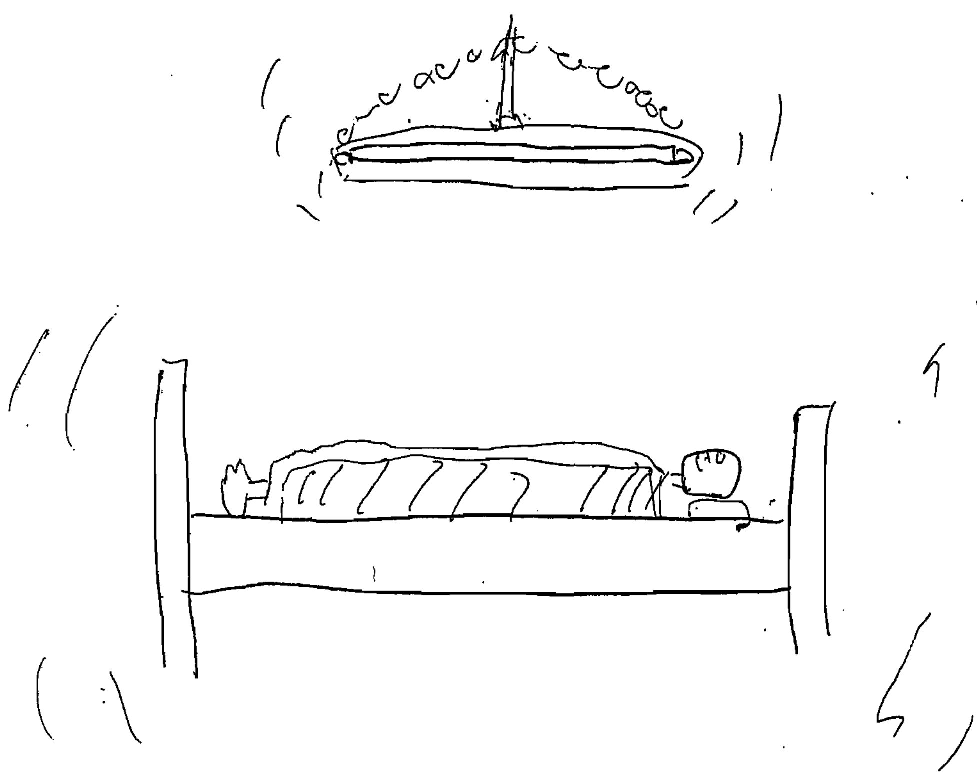
Appendix 69 An Earthquake/ Senior High School Year 3



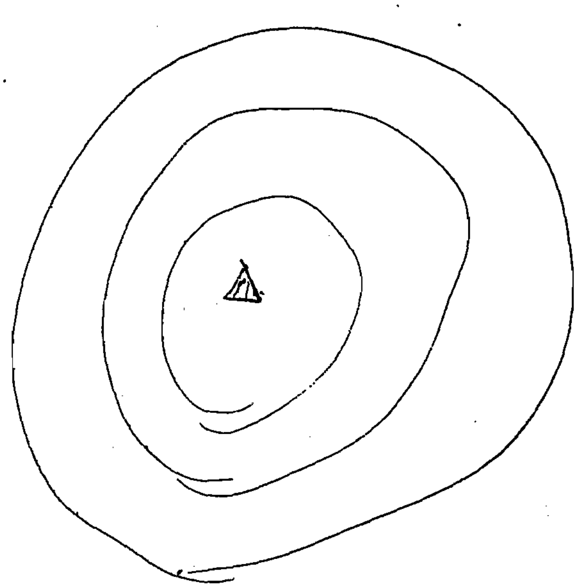
Appendix 70 An Earthquake/ Senior High School Year 3



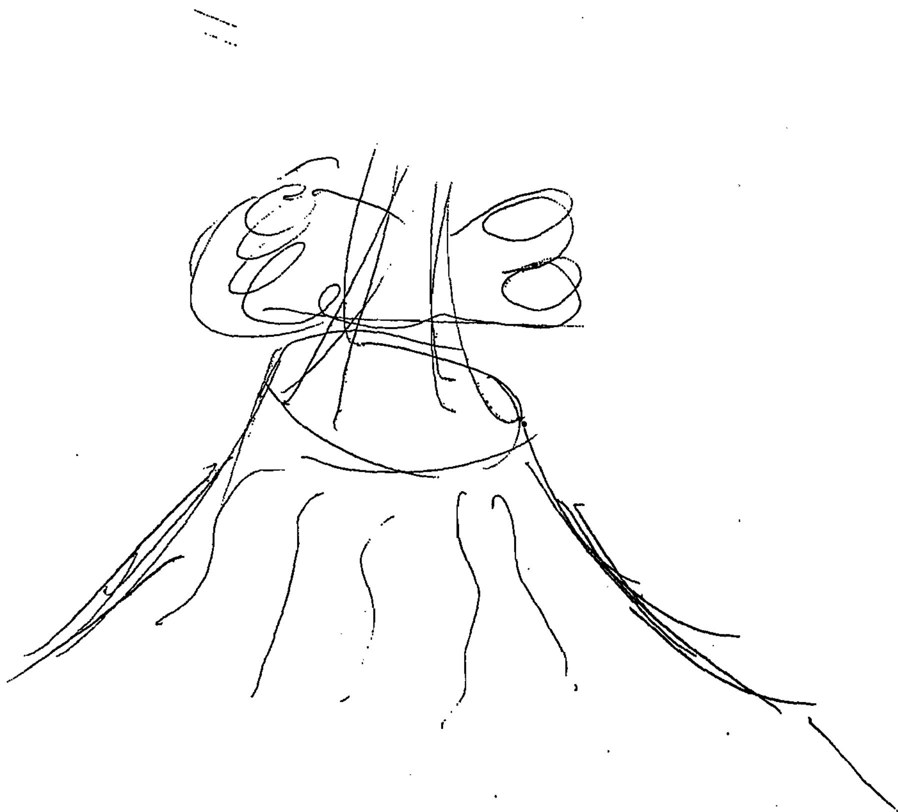
Appendix 71 An Earthquake/ Senior High School Year 3



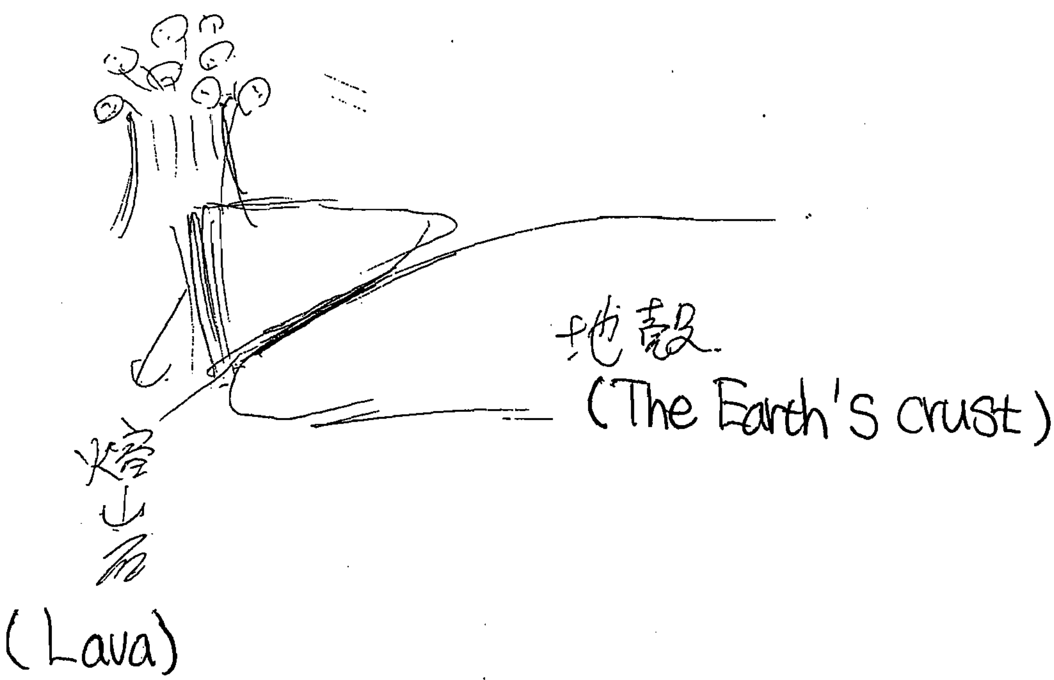
Appendix 72 An Earthquake/ Senior High School Year 3



Appendix 73 A Volcano/Senior High School Year 3

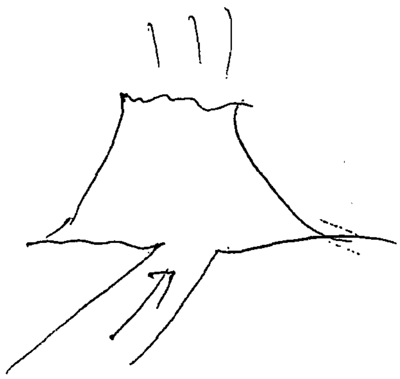


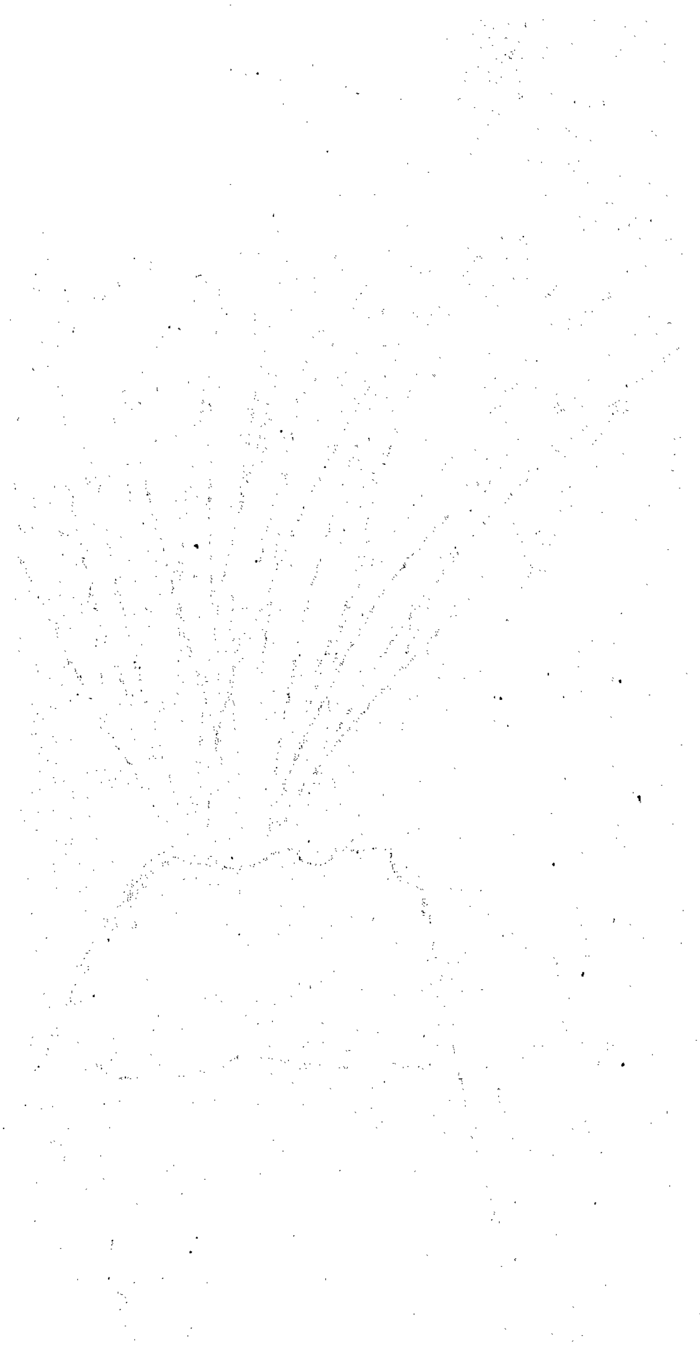
Appendix 74 A Volcano/ Senior High School Year 3



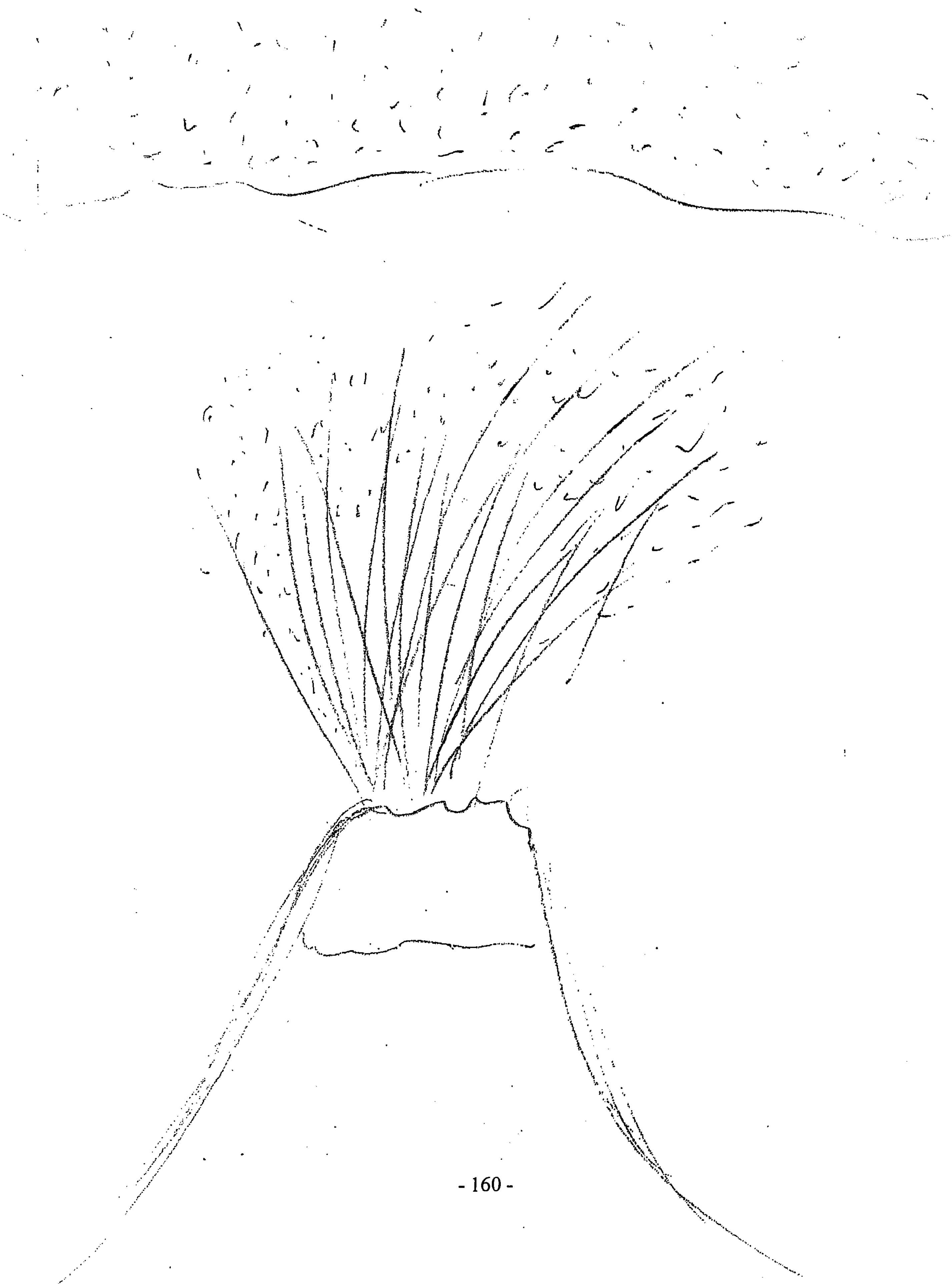
Appendix 75 A Volcano/ Senior High School Year 3

Appendix 76 A Volcano/ Senior High School Year 3

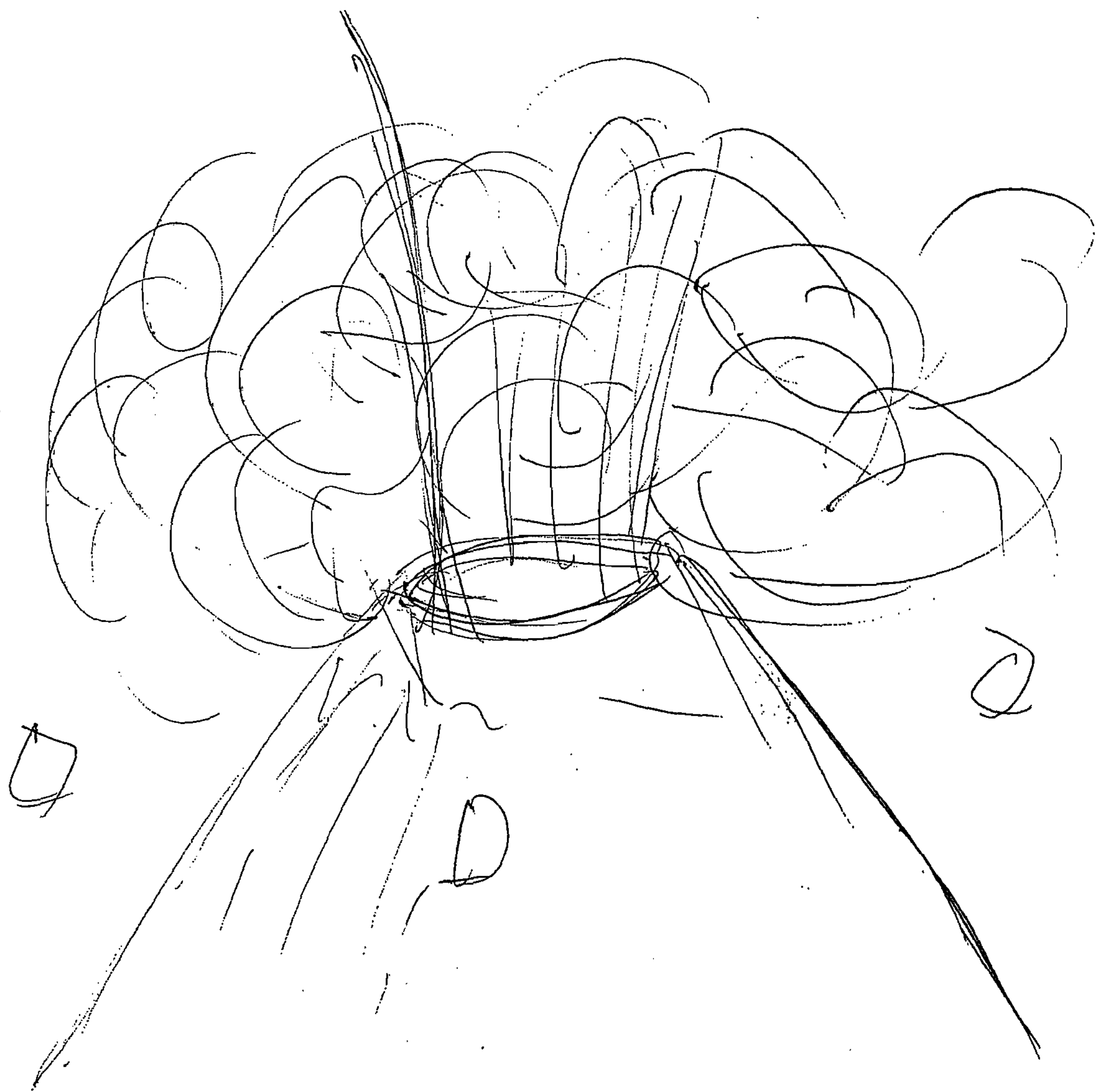




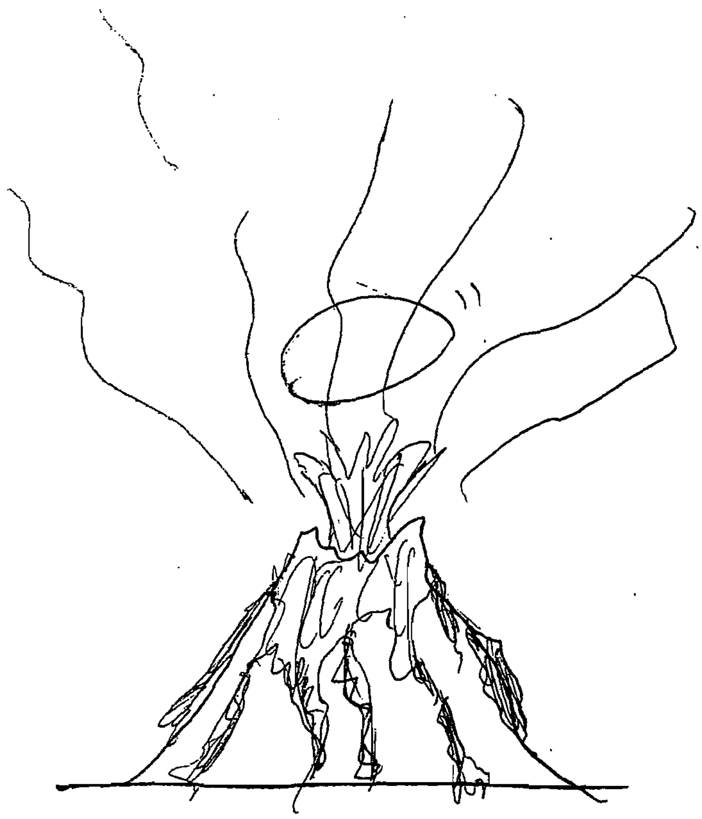
Appendix 77 A Volcano/ Senior High School Year 3



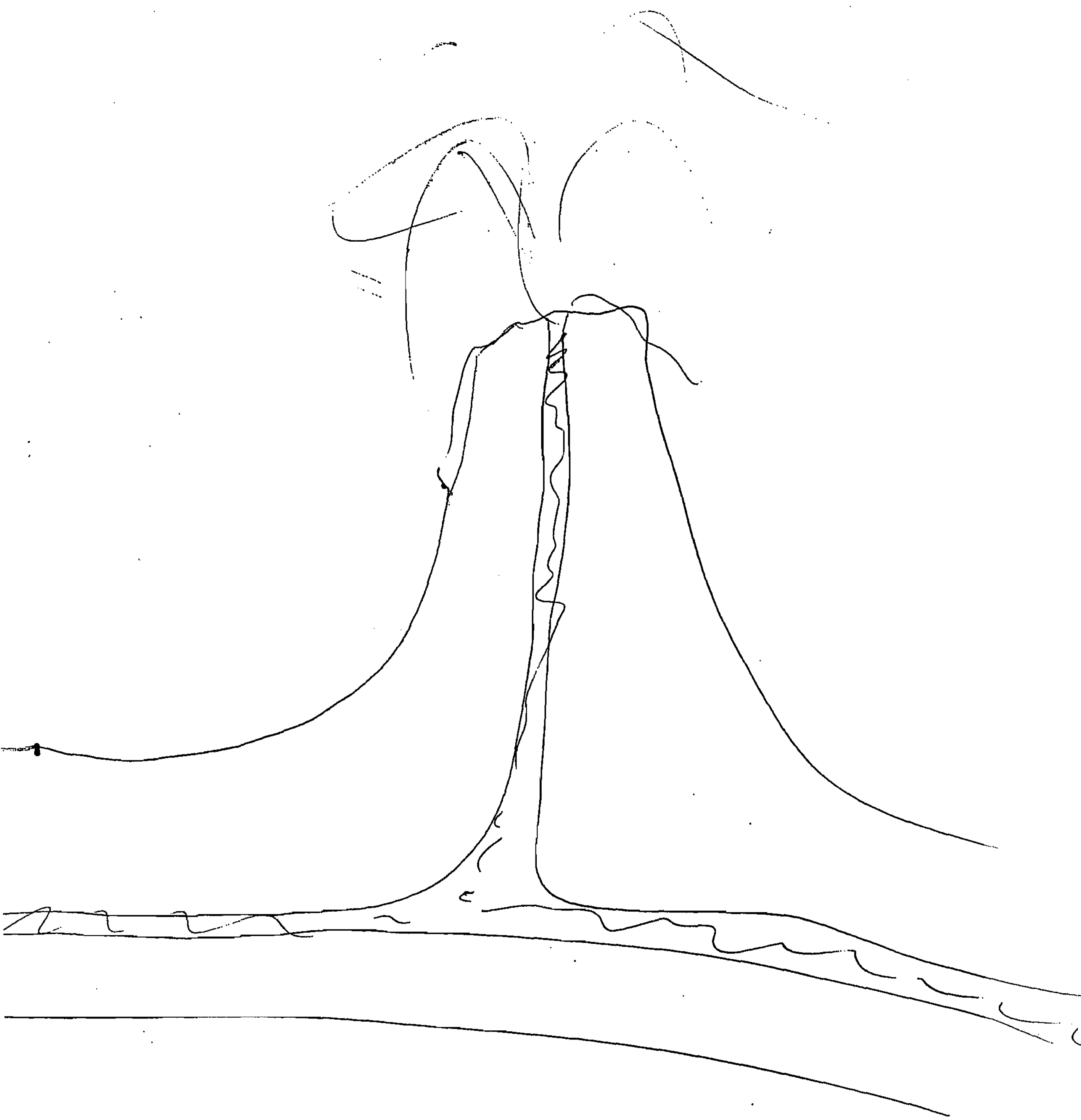
Appendix 78 A Volcano/ Senior High School Year 3



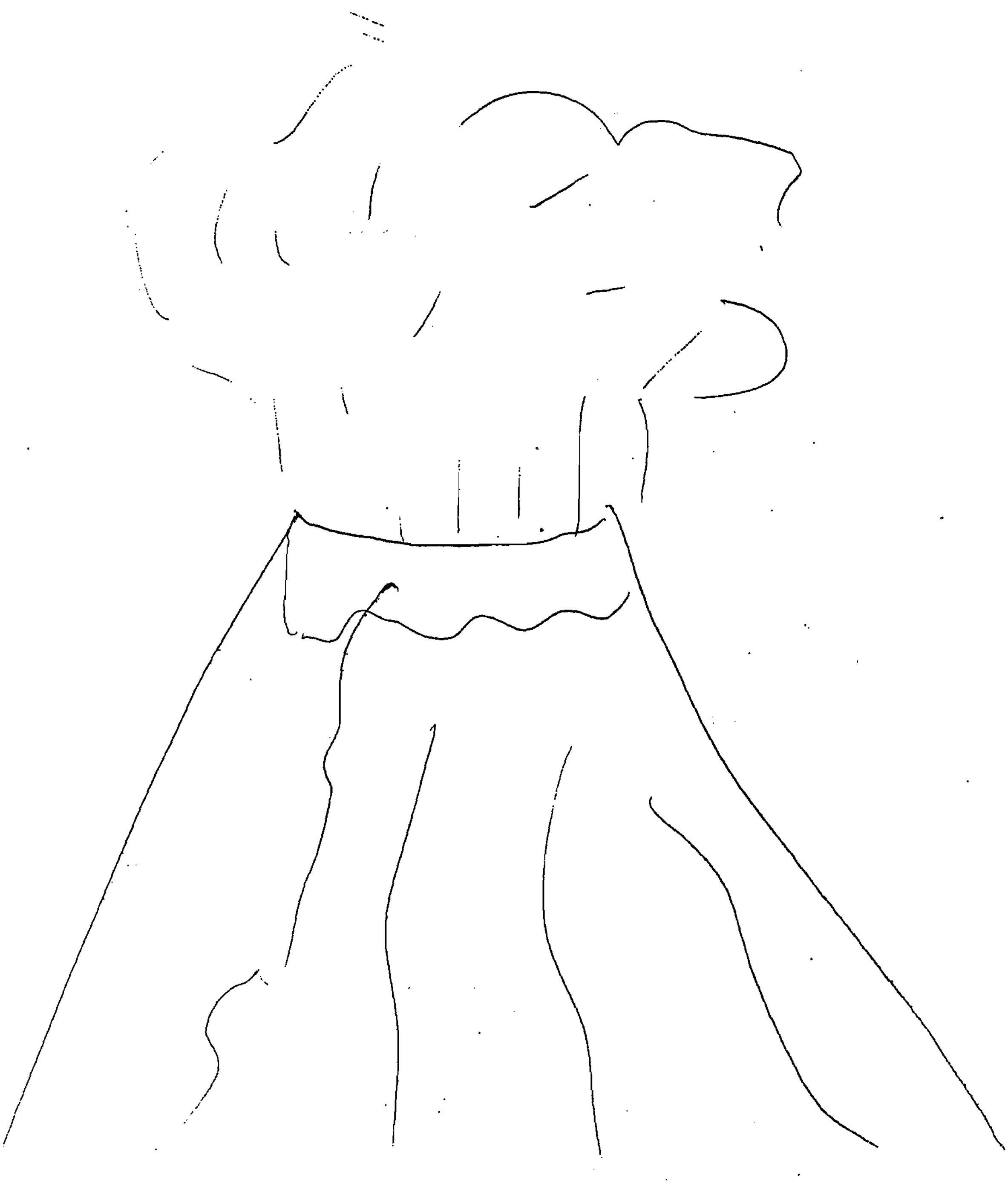
Appendix 79 A Volcano/ Senior High School Year 3



Appendix 80 A Volcano/ Senior High School Year 3



Appendix 81 A Volcano/ Senior High School Year 3



Appendix 82 A Volcano/ Senior High School Year 3