# BRAZILIAN PRIMARY TEACHERS' CHANGING CONCEPTIONS OF EARTHQUAKES

by
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Abstract

The 1986 earthquake series in João Câmara, Brazil, provides the context for this study. Its focus is on the experiences and views of primary teachers in the region. Experiences and conceptions about earthquakes are discussed in relation to scientific knowledge available.

This study examines the teachers' experiences and their use of a particular teaching/learning methodology based on Paulo Freire's principles of problem-posing education. It also considers questions related to the gap between scientific knowledge and teachers' and lay people's commonsense knowledge.The study conducted with primary teachers consisted of interviews. Data derived from the interviews is essentially qualitative. Results are discussed in terms of understanding the implications of the job of education in conceptual change. Education should be able to guide students in move from the immediate and concrete way of thinking about reality to a more organized and reflective way. Discussion of concepts of earthquakes held by teachers and conceptual change among teachers is addressed.

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To my parents,

Elza and Enoque (in memory), who taught

me to never give up  a dream.

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# CHAPTER I

## 1.1 Natural Disasters

Globally, the occurrence of natural disasters such as those caused by earthquakes, windstorms, tsunamis, floods, landslides, volcanic eruption, wildfires, and other calamities has increased, and over the past two decades have killed 3 million people and adversely affected the lives of at least 800 million more people (Weisaeth, 1993, p. 391). Berz shows that 109 natural disasters occurred between 1960 and 1987. In a survey (Berz, 1989) of 41 disasters, the number of deaths that occurred in developing countries was 758,850 compared to only 11,441 in developed countries.

Because of natural disasters, more and more people in one way or another have had to deal with major changes in their lives. For example, people have had to move from their homes, have had to live in shelters for a period of time, and have had to deal with lack of resources, privacy, and sleep. When faced with a disaster, a high level of uncertainty becomes part of people's daily lives. Questions have been included, such as: Is my home safe? Am I going back home? Is it going to happen again? When is it going to happen again? People have had to make difficult and sometimes painful decisions based on their perceptions of each specific situation. They have coped with understanding the severity of the event, leaving their possessions behind to save their own lives, having to decide which child to rescue first, or even giving permission for a rescue team to amputate one of his/her limbs in order to be saved. Even with their knowledge and understanding of everyday life, they are not able to answer many questions raised by these new situations. In the case of earthquakes, questions might be: What is an earthquake? Why is it happening? What can I do to protect my family? It is necessary for individuals to make conceptual adjustments to cope with new reality, brought on by a disaster. In the example presented in this study, people have had to learn that they could no longer believe that there was no possibility of earthquakes occurring in Brazil. And that earthquakes can happen any time and anywhere.

Education is considered to be an important tool in recovery from disaster impacts. Nonetheless, little has been done regarding the inclusion of subjects related to disasters in school curriculum or in the production of materials that discuss the implications of disasters in our lives (Lidstone, 1992; World Commission on Environment and Development, 1987; World Conservation Union IUCN, United Nations Environment Programme UNEP, and World Wide Fund for Nature WWF, 1991; Varley, 1994). Most of the material available has been produced by professionals from backgrounds other than education.

Despite the importance of the topic of natural disasters and teachers' concerns about how to address it in the classroom, information given to teachers, and teachers participation in disaster related activities have been limited (Ross & Suell, 1993). Usually, the most accessible materials available to teachers and schools on disasters are in the form of posters and pamphlets. These materials concentrate more on basic information for a specific disaster. Information is most often limited to telephone numbers, and drill instructions, rather than on discussion about the phenomenon itself, the scientific concepts involved, and the possible consequences for people's lives ( Lidstone, 1992 ). With better education and use of scientific information and technology, many lives may be saved (Alexander, 1993; Weisaeth, 1993).

## 1.2 Earthquakes in João Câmara

In 1986, one of the longest series of earthquakes started in João Câmara, a municipality in the state of Rio Grande do Norte in the Northeast Region of Brazil. From 1986 to 1993, the Geophysics Research Group of the Federal University of Rio Grande do Norte registered, as well as studied, more than 43,000 events. During this period, observations included phases of intense activity followed by phases of less but continuous activity. There was much material damage. Although there were no deaths as a result of the earthquakes, the persistence of the tremors affected the psychological well-being of the population (Ferreira, Takeya, Costa, Moreira, Assumpção, Veloso, & Pearce, 1987; Assumpção, Ferreira, Carvalho, Blum, Menezes, Fontenele, & Aires, 1989; Dal Pian, 1993).

Due to uncertainty (e.g., why the earthquakes were happening, when they were going to stop, and when they would happen again), the local population formulated a growing number of explanations. These various explanations were an effort to understand the phenomenon of earthquakes and to cope with a frightening situation. Some common explanations used by the general population were the following:

> *This is the end of the world... The earth is going to open and hell's fire is going to burn everything. This is the dragon or the big whale that lives inside the earth, and some times wakes up and moves, making the ground shake and rocks to fall inside the earth* (see Appendix A for other examples).

These beliefs about earthquakes were gathered by the *Education, Science and Technology Unit* (ESTU) of the Federal University of Rio Grande do Norte. This multi-diciplinary group of researchers, working together with teachers of São Paulo do Potengi were able to identify different views about the causes of earthquakes during the first stage of the process for the development of the seismicity module. I will discuss such process in detail in Chapter II.

The Brazilian news media focussed on the earthquakes in João Câmara and made available a large amount of information to the public, such us pictures and images of the houses destroyed during the events, and trucks and buses filled with people who were abandoning the region. Images of people in despair, e.g., crying in the middle of a nervous' attack, were juxtaposed against interviews with politicians about governmental support for victims. Explanations about earthquakes by affected persons were joined by news media explanations of earthquakes based on scientific and technological studies. These explanations were provided through interviews with specialists in seismology, geology, and other related scientific areas, in an attempt to give people in general accurate information about the events. In the interviews, the specialists tried to express in simple terms the scientific theories used by scientists to understand and explain the occurrence of earthquakes in the region, and they tried to correct the false belief that Brazil's territory is free of earthquakes. Unfortunately, despite efforts by specialists to reach the population and to clarify the situation in relation to factual events, the climate of panic persisted among the people affected. With media coverage, fear and uncertainty became widespread amongst the people in São Paulo do Potengi. Also because of fear, people migrated from João Câmara to other cities, such as São Paulo do Potengi the site of this study.

Persons who migrated from João Câmara provided the same type of mythical explanations for the earthquake phenomena as the people of São Paulo do Potengi. These explanations did not satisfy the primary school teachers at São Paulo do Potengi. Migrant children from João Câmara joined the students of São Paulo do Potengi and raised many questions about earthquakes. Teachers were unable to provide adequate answers. Because students wished to discuss tremors they had experienced the night before, teachers themselves started questioning their own explanations. They become puzzled about the phenomenon. They discovered that their scientific knowledge of earthquakes to be limited and that their explanations were based on their own biases. They also discovered that they were unable to sufficiently understand the information provided by the media, and they started seeking reliable sources for help. Assistance from the Education, Science, and Technology Unit (ESTU) of the Federal University of Rio Grande do Norte was sought. Recent positive experience with the Unit prompted their request for the study of seismicity. Such experience involved production of instructional materials, reformulation of science curriculum, and development of teaching/leaning methodology based on the Freirean approach (see Chapter II for details). Following the proposal, topics were developed, including Drought, Water and Diseases, and Agriculture – all of which were identified as problems affecting the population in that community. The teaching/learning methodology adopted, seemed to enhance understanding and raise peoples' disposition to encounter the unfavourable conditions encountered in their community. As a result, teachers believed that by adding a module on earthquakes to the science curriculum, it would be possible to help people to overcome their fears and uncertainties about the future.

### 1.3 The Seismicity Module

Together with a group of multi disciplinary professionals, teachers gathered information about people's beliefs about earthquakes. The information gathering activity set the stage for meaningful discussions about seismicity. Consequently, teachers and researchers planned and produced units and activities for children in the schools. Once complete, the developed module (see Appendix B) was immediately implemented into the classroom. Sometimes, activities in the module were conceived and developed in a week and used in the classroom the following week.

Inspired by Freire's work (see References), the seismicity module was conceived using a thematic approach. The module included detailed instructions for each lesson, reading materials, written exercises, laboratory procedures, and slides.The module consisted of four main units/themes: The first unit discussed the *Effects of Earthquakes*; the second, discussed the *Shocks Travel*; the third showed the *Earth's Interior*; and the last one examined the *Causes of Earthquakes*. The teaching/learning material explored the theories of continental drift and tectonic plates to explain the occurrence of the earthquakes.

### 1.4 Rationale for the study

This study is framed into the research developed by the ESTU. The research focus on the restructurization of the teaching of science within a ploblematazing approach. Research has been concentrated in two different settings: a rural, the municipality of São Paulo do Potengi and an urban, the district of Potilândia in Natal.

Amongst the activities that have been developed by the group is the development and implementation of four teaching modules which were built from the following generative themes: *Drought and Water, Agriculture, Seismicity and living.*

Activities developed with these modules have pointed to the existence of a relation between students' difficulties in the understanding of the various topics discussed and their understanding of different concepts, such as life, energy, and area. Furthermore, it has motivated the development of research in this direction. On the other hand, the work which had been developed has required, from the beginning, other knowledge, regarding the learning process and the development of concepts. Consequently, it was necessary to study the topic of conceptual change.

The development of the activities presented in the modules referred above, have taken into account approaches which take in consideration Piaget's (1967,1971) view in relation to knowledge construction and the existence of cognitive stages, as well as aspects which were specifically consider by Vygotsky (1986, 1994) in respect to the social construction of knowledge. In other words, we can say that such aspects of the learning process were taken into consideration through the use of objects and themes from the students' socio-physical- cultural context, as well as in the practice of dialogues which have leaded to new explanations and concepts.

During this phase of the research, themes related to concept construction and conceptual change had not been studied. However, the necessity of such kind of study had become clear, specially in the case of earthquakes. The study of earthquakes brought up a situation where teachers and students had the same kind of mythical explanation for the phenomenon. Teachers were not satisfied with their own views and decided to learn to better understand the topic and teach their students.

This context constitutes, therefore, the main motivation to the realization of this study.

## 1.5 Research Questions

I was curious to find out the view's teachers have about earthquakes, particularly in the context of their own experience. I wanted to understand how the events motivated their conceptual change. I wanted to gain a descriptive picture of how conceptual changes occur in the attempt to identify possible stages or the actual motivation for such changes. Hence I asked the following questions:

1. What were the experiences of the teachers in São Paulo do Potengi during the earthquakes of 1986?
2. How did teachers' perceptions and concepts of earthquakes change as a result of their experiences?
3. How did the seismicity module direct their perceptions and concepts in their teaching about earthquakes?

Answers to these questions may provide a link between school science curriculum and natural disasters (eg. earthquakes) affecting children's daily lives. The teacher's knowledge of the phenomenon of earthquakes may perhaps best be interpreted as a knowledge necessity and teaching about earthquakes as teaching/leaning methodologies. The questions posed may also raise further questions related to bridging the discontinuity between daily life experience and scientific ideas taught at school.

Relevance of my study is tied to two factors: First, it examines teachers' concepts and the changes observed in those concepts after studying in a changed context, in a secure environment, and with a new way to look at the world. Secondly, it presents the opportunity to observe difficulties faced by people in the process of conceptual change in perceptions and facts.

## 1.5 Thesis Organization

In the remainder of my thesis I will paint a broad picture of the subject of earthquakes, and present Freire's ideas of education, which were used in the development of the science module. Chapter II presents the developed science module, and how it was implemented in the classroom. Chapter III describes the protocol used in this research to collect and analyse data designed to answer the research questions. Chapter IV presents the findings in answer to the research questions. Finally, chapter V summarizes conclusions and implications arising from my research and offers recommendations for further research.

# CHAPTER II

## 2.1 Introduction

This chapter focuses on the experiences of the teachers in the earthquake affected schools. Particular attention is given to how these teachers translated their experiences and perceptions about earthquakes into classroom exercises and dialogue. To understand the process of conceptual change and transference of perceptions and ideas into materials to teach students, it is necessary to know not only national and international information and views on earthquakes but also to know the context in which the teachers work, including:

- Beliefs about earthquakes
- Historical development of the knowledge of Seismology
- Scientific explanation for earthquakes
- Context of the study
- Primary education in Brazil
- Freire's ideas on education
- Science curriculum developed using Freire's principles
- Development of children's conceptions and scientific knowledge
- Obstacles to teach about earthquakes
- Seismicity module

## 2.2 Beliefs of Earthquakes

Causes of earthquakes have been a mystery for a very long time. Because one cannot directly observe the causal agents, a variety of explanations have arisen in a number of cultures at different times in history.

Aristotle (384 - 322 B.C.) believed that wind escaping from caves within the bowels of the earth caused mild earthquakes. Gales that find their way into great subterranean caverns created severe shocks (Levy & Salvadori, 1993).

The Maori of New Zealand believed that Ruaumoco, the God of volcanoes and earthquakes, was accidentally pressed into the earth as his mother turned his face downward while feeding him. Belief is that Ruaumoco has been "growling and spiting fire ever since"(Levy & Salvadori, 1993).

Ethnic minorities in the Yunnan Province in the Southwestern China believed that tremors resulted when a great dragon moved underneath the ground. The dragon wanted the earth to turn over because the beast was unhappy and angry. Some believed that there are several dragons, including the evil father and the good son (McFarlane & Hua, 1993).

Ever since pre-historic times, people have described such violent and unexpected acts of nature to result from acts and interactions of supernatural forces. Nowadays, the causes have been scientifically investigated and are generally better understood. However, the innate power and effects of a disaster such as an earthquake still promotes belief in myth rather than reality (Weisaeth, 1993).

Mythical explanations of the phenomenon of earthquakes, and the model for earth's structure, arise mainly from immediate observation of the surrounding world (see Appendix C for teachers' model of earth structure). One such example is the model of the earth's interior, filled with caves, and rivers where giant animals, such us dragons, wales, and snakes, live. Present in many of those models is the persistent search for a way to predict the occurrence of earthquakes. Some of these explanations result from compilations of data collected from observations and eyewitness reports about the events, as well as scientific knowledge available at the time. Over the years, lay people and scientists have taken on the challenge of finding ways of predicting such events.

A recent study, carried on by German scientist, Helmut Tributsch (1993), collected data from different events around the world and compared them with descriptions of different events throughout history. The objective of the study was to formulate a possible scientific explanation for the observation of specific events prior to the occurrence of earthquakes. Those events are called predictors and vary from abnormal animal behaviour to changes in the weather. Such events have been largely present in lay descriptions of earthquakes, as well in some scientific attempts to find ways to predict earthquakes.

Examining the Bible, for example, it is possible to find revealing episodes of destruction, such us the Deluge, and the destruction of Sodom and Gomorrah, which could be interpreted as indicators of earthquake occurrences, despite the fact that earthquakes are not directly mentioned in the holy texts. Possibly, the biblical inference is that a powerful phenomenon such as earthquake is due to the appearance of God Himself to man (Tributsch, 1983).

Tributsch's view is that many of the destructive episodes narrated in the Holy Book might have been, truly, the results of powerful earthquakes. For example, in Exodus 19:16, when God met Moses and the people on Mount Sinai, the episode describes that there were thunder and lightening, a thick cloud was seen upon the mountain, a very loud noise was heard, which was described as a trumpet blast, and the whole mountain quaked. Such descriptions can be related to other reports from different times, such as a description of a victim of a event occurred in June 1560 in the municipality of São Vicent, located in São Paulo state, which describes the occurrence of a strong storm followed by a horrible quake in the southeast Brazilian city. Therefore, it is not difficult to understand why people tended to interpret such shocking experiences as indications of God's presence on earth. Maybe because of its great power and unexpected occurrence, earthquakes have always been attributed to supernatural forces or great mythical creatures. Throughout history we are reminded that there is no natural event more violent, destructive, and shocking than a severe earthquake. No natural disaster is more unpredictable. Almost everyone who has experienced a harsh earthquake recognizes that he/she has never been in such a helpless situation.

Earthquakes traumatize the soul and nerves, as well as making a person to re-evaluate life's priorities (Tributsch, 1983). Any wonder in ancient times people from different cultures and religions believed that earthquakes were demonstrations of divine powers. People continue to this day to turn to religious or mythological explanations.

### 2.3 Historical Development of the knowledge of Seismology

According to Wijkman and Timberlake (1986), earthquakes are the most poorly understood and least predicted of all natural disasters. It is also the hazard that directly kills more people each year than any other hazard. At least 35 countries in the world are regularly affected by earthquakes (Smith, 1995, p. 103).

For a long time, science failed to achieve a comprehensive model of explanation for the occurrence of earthquakes. Consequently, science reverted to the explanations provided by a range of people. Explanations varied from *deep volcanoes* to *planet-girdling tunnels through which* *quakes travelled around the globe* (Wijkman & Timberlake, 1986, p. 81). Mostly people have clung to the belief that earthquakes are *acts of God*.

Although early scientists and philosophers expounded on the phenomenon of earthquakes, it was only in the middle of the eighteenth century that the hazard received scientific status. The subsequent section describes some of the most important technological and scientific advances in the development of seismology.

### 2.3.1 Waves

Seismic waves will propagate from the focus of an earthquake as a stone thrown in water generates waves from the point of impact. The source of a quake is a sudden movement between two adjacent rocky blocks which is erratic in action. An earthquake is, then, simultaneously a rupture generating waves and transmitting them. Those two aspects, rupture at origin and wave generation and propagation, are the two bulwarks inseparable from the science that has the seisms as object of study -- seismology (Bolt, 1978; Allègre, 1993; Levy & Salvadori, 1995).

### 2.3.2 The Seismograph

In its primitive version, the seismograph was created in China around 1032 (Allègre, 1993, p. 52). But it was only at the end of the nineteenth century that Von Reuber Paschwitz (Allègre, 1993, p. 52) noticed that with the use of a very sensitive pendulum it was possible to detect an earthquake originating hours before in a far distant place. Subsequently other seismographs were developed and improved. All of them were built according to the same principle: an inert mass, a support linked to the ground which has a recorder, and a spring connecting one to the other. Ground motion slightly displaces the instrument, and a pen connected to the inert mass registers the vibration.

### 2.3.3 Intensity Scale

Before the development of such an instrument, the effects of the earthquakes were measured by determining the destructiveness of impacts. In other words, earthquakes were strictly reported as physical damage to structures and infrastructures and people's reaction to the event. It was mainly a qualitative way to measure earthquakes. Robert Mallet, in 1857, drew the first map of the impacts of an earthquake (Allègre, 1993, p. 50). He simply linked the points of equivalent damages on a map. Mapped lines were referred to as intensity curves. He was able to identify sites of maximum damage and referred to them as the epicentre of the eathquake. The intensity of a quake was consequently taken to be a function of the measurement of its effects. The first intensity scale was developed in 1880 by the Italian Rossi and the Swiss Forel (Allègre, 1993, p. 51). In 1902 , the Italian Mercalli improved it and proposed a ten-step scale which become widely accepted among seismologists due to its more detailed and specific gradation (Levy & Salvadori, 1995, p. 77). In 1931 a consensus was reached by seismologists on the adoption of a modified Mercalli Scale, describing twelve levels of intensity varying from I (not felt by the majority of people) to XII ( total destruction) (Levy & Salvadori, 1995, p. 77).

### 2.3.4 Magnitude Scale

The second series of systematic studies done from the seismograms were centered around measurement of the quake energy. It was taken that the stronger a quake is, the stronger would be the vibrations emitted by the quake. The amplitude of the seismic waves emitted by an earthquake depends on the force inherent in the ground wave. In considering amplitude as a measure distance from the center of the seismic activity to the measuring point had to be a factorial in the equation. The scale was expressed as the logarithm of the amplitude. Thus, an earthquake of magnitude 6 is ten times stronger than a quake of magnitude 5 and one hundred times stronger than a quake of magnitude 4. This scale of magnitudes was created in Japan by Wadati in 1931, and later improved by Richter in 1935 (Wijkman, & Timberlake, 1986; Allègre, 1993).

### 2.3.5 Continental Drift Theory

On January 6, 1912, the German meteorologist and geologist/geophysicist Alfred Wegener, made public a radical theory to explain how the earth works (Gohau, 1990; Oldroyd, 1996). His main idea was that the continents were once in the past joined together and thereafter they drifted over the ocean floor, to reach their present positions. His ideas were inspired, at first, by observations about the shape of the African and South American coasts. He noted that they could fit together like pieces of a jigsaw puzzle (Gohau, 1990). Later, Wegener found geological evidence, such as similarities in geological formation and results of studies on fossils of plants and large animals, which indicated a strong connection between the terrain of the two continents. As any other theory which challenges current comprehension of how things operate, his theory faced enormous opposition and was not immediately accepted. Especially because prevalent belief at the time was that the earth was going through a period of cooling off and was contracting. This belief was used to explain the occurrence of all geological phenomena known, such as earthquakes, volcanos, and mountain formation.

Despite the efforts of Wegerner and his supporters to promote the continental drift theory, it was not accepted and it remained obscure until the 1960s, when it was reformulated with support of new evidence and incorporated to a new theory: the Plate Tectonics Theory (Gohau, 1990; Allègre, 1993; Levi, & Salvadori, 1995).

### 2.3.6 Plate Tectonics Theory

The Plate Tectonics Theory, accepted only in the late 1960s, is now considered to be the most conceivable explanation for the phenomena related to the placement of the land masses on the earth and the events of earthquakes, volcanos, and tsunamis. Original publication of the ideas revealing the path to the theory appeared in the *Journal of Geophysical Research* (Isacks, Oliver, & Sykes, 1968). These authors were the first to coherently link seismic studies (Allègre, 1993, p.21). In their model of plate tectonics, they noted that the regime of operation of earth movements occurred in the rigid crust of one hundred kilometers thickness girdling the earth. Further, they postulated that the crust was cut into a number of geographic and independent provinces that they called plates. Movement of the plates, over a distance of about 50 millimetres (2 inches) per year on average, was taken to result from their sliding over a plastic layer surrounding the earth's molten core. The exact mechanism of movement of plates is due to convection currents consisting of upward motion of particles rising through the earth's mantle from the molten core (Allègre, 1993; Levi & Salvadori, 1995).

## 2.4 The Scientific Explanation for Earthquakes

Earthquakes are generally described as a sudden movement of plates, caused by the release of stresses and elastic energy, accumulated over geologic time. Elastic energy can be generated by movement of continental crust fragments, volcanic eruptions, or even by man-made explosions.

Earthquakes of high magnitude do not necessarily cause the most destructive effects on the earth's surface. The effects of an earthquake will depend on the geological conditions in the region. For example, in areas with an unstable surface, such as sand, clay, or any other unconsolidated materials, experience more perceptible effects than areas in which the surface is composed of compact materials, such as granite, and gneisses

Areas of highest seismic activities are located along plate tectonic boundaries. Such areas include: divergent boundaries, convergent boundaries, transform-fault boundaries, and plate boundaries (Kious & Tilling, 1994; http://www.gsrg.nmh.ac.uk).

Divergent boundaries are the regions where two plates move away from each other and a new crust is created by magma rising from the mantle. For example, divergent boundaries are seen in the central part of the mid oceanic ridges, in the middle of the Atlantic and the Pacific oceans. In these regions the earthquake's focus are shallow.

Convergent boundaries are regions where plates approach and collide with each other or, in some cases one plate pushes beneath another. For example, convergent boundaries occur in the Andes and Himalayas mountain chains. In these mountain ranges, slow but continuous convergence of the plates over millions of years has pushed them upward or sideways, giving rise to their extreme height and shape. In these regions, the earthquake's focus are both shallow and deep.

Transform-fault boundaries are regions where plates move alongside one another and manifest strike-slip displacement. An example of such boundaries is the San Andreas fault in the west of the United States. These regions are characterized by more frequent and stronger earthquakes, since their generation is in a shallow focus.

Plate-boundary zones are regions where at least two large plates and one or more microplates interact. One example is the Mediterranean-Alpine region, located between the Eurasian and African plates. Because of their complexity, they tend to have complicated earthquake patterns.

Earthquakes can also be generated in the central region of plates. Such occurrences are rare and more difficult to explain. Because of the possibility of earthquakes anywhere over the surface of plates, there is not a region on the surface of the earth which is free of earthquakes.

In Brazil, quakes of small magnitude have ben caused by superficial weakness and shallow faults. Also, earthquakes of high intensity, with epicentres located in the Andes' region, are felt in the large cities located in the south and south east regions of Brazil.

## 2.5 Context of the Study

The present study was developed with the professionals of the São Paulo do Potengi public schools. São Paulo do Potengi is a city located in Rio Grande do Norte State, Brazil. It has approximately 14, 812 inhabitants (Instituto Brasileiro de Geografia e Estatística, IBGE) residing in the main town and small villages. It is 78 km from Natal and is located in the agreste. Its economy is agricultural, based on the cultivation of crops (cotton, beans, manioc, Cajun nuts, corn, sisal) as well as mining of natural vegetation (charcoal and firewood), and the production of herds (cattle, pork, chicken, horse, goat). The municipality maintains public and private schools through the high school level. There is no college or university in the municipality.

The earthquakes considered in my study took place in the municipality of João Câmara. The city of João Câmara has approximately 29,227 inhabitants (Instituto Brasileiro de Geografia e Estatística, IBGE ), distributed in the main town and small villages. It is 75 km from Natal, the capital of Rio Grande do Norte State. João Câmara is located in the sertão, and its economy is basically similar to São Paulo do Potengi. Educational opportunities are also similar to those of São Paulo do Potengi.

Rio Grande do Norte state is one of the most easterly of the Northeast region of Brazil. It consists of three subregions: zona da mata, agreste, and sertão, and has an area of 53,077.1 square kilometres with a population of more than 2,771,538 inhabitants (Instituto Brasileiro de Geografia e Estatística, IBGE).

The Northeast region comprises an area of 1, 548, 672 square kilometres, equal to 18.2 percent of the National territory, with more than 47, 000, 000 inhabitants (Instituto Brasileiro de Geografia e Estatística, IBGE).

Based on local characteristics, this region is subdivided into four subregions: The forested zone (zona da mata) has a warm climate and two well defined seasons, one wet and other dry. The thorn forest (sertão) has also a warm climate but dry, and is exposed to severe periodic droughts. A transitional zone (agreste) is located in between the other two regions. It has a diversity of landscape within a very short distance. Hence, it is a complex mixture of the two other regions, with the alternation of wet (brejos) and dry areas (caatinga). The northern region (meio norte) is located between sertão and amazonic area and has a humid climate.

Brazil is divided into five natural regions (North, Northeast, South, Southeast, and Middle West Region), which present unique characteristics in landscape, climate, vegetation, and hydrology. The country has an area of 8,514,215.3 square kilometres and a population of more than 169,590,693 (Instituto Brasileiro de Geografia e Estatística, IBGE). This study took place in the Northeast region of Brazil, which is located at the eastern most extremity of South America.

### 2.6 Primary Education in Brazil

Primary education in Brazil is compulsory and free. The National Constitution of 1946 established education as compulsory for the first four years of schooling, which were subsequently expanded to eight years by the Constitution of 1969 (Romanelli, 1986). These eight years correspond to children ages between 7 and 14 years. However, in reality, primary education in Brazil shows a difficult picture. Despite the growth in number of primary schools over the years, there is still a large number of children and young adults out of school. The challenge faced by the school system in relation to the high number of drop outs among working-class children is well known. Addressing illiteracy and drop out rates constitutes the center piece of a long and controversial debate on educational in Brazil.

It is also well known in Brazil that working-class children, who are the overwhelming majority of children attending public schools, start attending school later in their lives. This situation is due to the fact that eight to ten years old children are often expected to work to help the family and therefor withdraw from school. This phenomenon is more dramatic in rural areas, compared with urban areas.

For teachers the expansion policy implemented in the public system of education has proceeded without any major commitments to making available the required number of professionals to meet the demand. This has generated many problems related to the quality of teaching in schools. Employment of non-qualified professionals and low teacher salaries hae contributed to the decline in quality of education.

Overcrowded classes, unsuitable curriculum, and lack of basic equipment and materials (such as chalk, desks, and chairs) is the daily reality faced by many teachers and students in their schools. As well, many schools have had to close because their buildings are damaged beyond repair and no funds exist to replace them.

The conditions of education in Rio Grande do Norte state are described in Crianças e Adolescentes no Rio Grande do Norte – Saúde, Educação e Trabalho [Children and Young Adults in Rio Grande do Norte – Health, Education and Employment](1993), a publication of Rio Grande do Norte state government in partnership with UNICEF.

According to results of a national home by home survey, the number of children aged 7 to 9 years and attending school was 83.3 percent in urban areas and of 66.4 percent in rural areas. Children aged 10 to 14 years and in school was 84.2 percent in urban area and 74.3

percent in rural area. Overall the actual population of children of 7 to 14 years old in school was of 291,001 in the urban area and of 171,556 in rural area.

The illiteracy rate among children of age 10 to 14 years was of 28.5 percent, and of 15 to 17 years it was 20.7 percent. Overall the actual population of illiterate 15 to 17 years old was 102,925 in the urban areas and 55,593 in rural areas.

In 1990, only 11.2 percent of the children between 10 and 14 years had completed four or more years of schooling, while 77.4 percent had less than four years of schooling. The percentage of children between 15 and 17 years which had not completed four years of schooling was of 41.4 percent.

From each one hundred students registered to attend first grade, only 3 percent are able to complete grade eight within eight years.

Regarding teacher qualifications: (a) the number of teachers teaching the four first grades without qualification (no high school diploma or university degree) was 9.6 percent in urban area and of 54.0 percent in rural area; (b) the percentage of teachers with no qualification to teach grade five to grade eight (no university degree) was of 48. 5 percent in urban area and of 83.2 percent in rural area.

The following reasons are presented for the different results in terms of schooling between the urban and rural areas (Crianças e

Adolescentes no Rio Grande do Norte – Saúde, Educação e Trabalho, 1993):

In rural areas the attendance of the students in school is continually threatened by the conflict between the school calendar and the farming calendar.

Rural families are forced to flee droughts, thereby interrupting already agriculturally interrupted student attendance.

In terms of quality of schooling, public schools in the state are badly lacking in terms of physical space and in relation to a high number of non-qualified teachers working in the rural area.

These results reflect the inadequacy of the educational system in relation to the current demands of society. Schools have been rendered inadequate to provide the necessary changes to provide answers and solve significant problems which have arisen over the years. Quality education has been seriously compromised.

## 2.7 Freire's Ideas on Education

Paulo Freire, an internationally acclaimed Brazilian educator, developed his views on education inspired by a broad realm of intellectual traditions such as those of Marxism, Liberalism, Radical Catholicism, Existentialism, and Phenomenology, in his early productions, and Postmodernism and Poststructuralism in his later productions (Crotty, 1998; Roberts, 2000; Gadotti, 2001). Based on these intellectual traditions, Freire developed a methodology addressing illiteracy in Northeast Brazil in the late 1950s. His literacy and political consciousness program for the illiterates of Northeast of Brazil has been successful with educational campaigns and projects conducted in other regions of Brazil, Latin-American countries, and in African countries. In the last three decades, Freire's ideas have had a profound impact not only in the field of education, but also in many fields of national and international development. Abroad, Freire's ideas have had important influence in areas such as literacy, English as a second language, peace education, health education, adult education, and community development (Alfred, 1984; Wallerstein, & Bernstein, 1988; Graman, 1988; Butkus, 1989).

Freire (1970; 1992) begins his discussion on education by pointing out that educational practice suggests a conception of *human being* as *perceiver* and of the *world* as the *perceived.* Consequently, what defines human as a subject different from any other creature is his/her social creativity, capacity to shape the world by the invention of society and, hence, history. This process is realized through thought and language, which constitutes the possibility of the act of knowing through his praxis. Praxis is the relation between a person's critical thinking about the world and his/her consequent actions in it.

Based on his vision of what it is to be human, Freire (1970; 1992) defines knowledge as a dynamic process, which arises from the critical thinking and action in praxis. Thinking and doing, according to Freire, are indissolubly united. They must go together even in the temporal sense. Consequently one cannot be preceded by the other; they take place at the same time. When this occurs, they are creative, and constantly and mutually illuminate each other. His vision of education, then, emerges in support of his visions of the human condition and knowledge. It is founded on the principle of freedom, in which men and women discover themselves as active participants in the *act of knowing* and in the transformation of their reality.

Thus, learning to read and write is based on a method that involves discussing and reflecting about one's life. The result is a new level of consciousness and identity. Consequently, Freire reminds educators to begin looking critically at the social reality in which people find themselves. With this new consciousness of reality, people often begin acting in a way that transforms society, which has previously refused them an opportunity to participate.

Following this rationale, education is basically seen as a process intended to prepare the student to fully participate, not only in immediate social changes, but also in the construction of history. The purpose of education is primarily human liberation – an intimate connection between education and humanization. Thus, education involves humanizing, being critical, dialogical, and praxical. In practice, teaching to Freire (1970; 1992) is an act of transformation, which involves reflection and action. Hence, to educate it is necessary to promote reflection and action, thought, and reality. To foster this role, Freire proposed dialogue (Freire,1970, pp. 75-86) and problem-posing approach ( pp. 66-74).

Dialogue is a process of communication in which both understanding and significant changes which one makes are important. Dialogue incorporates inquiry and intervention. It begins when the teacher asks himself/herself about the subject of the dialogue that he/she will be conducting with the students. In Freire's method the subject matter depends on reality and people's perceptions of reality. Hence, program content is not a mere unfolding of scientific knowledge in its logical component topics. The methodology of investigation is *dialogical*, providing students the opportunity to generate and learn meaningful themes. Dialogue probes into thinking about reality and enables action upon that reality (Freire, 1970; 1986; 1992).

Freire's (1970;1992) theory of problem-posing in education starts with an analysis of a concrete situation. The existing situation is coded, based on its manifestation, revealing the interaction of its constituent elements and characteristics. Thus, to decode is to undertake a critical analysis of the coded situation. Problematizing becomes the central concept in Freire's theory. Problematizing does not constitute transmission of bits of information from one head to another. Making problematic both reality and people's perception of that reality means that problems need to be searched and themes unfolded.

Freire's ideas of codification and decodification (1970; 1992) of reality point to a methodology of teaching. It leads to a dynamic way of generating programs. Based on his principles, the school curriculum ultimately accommodates local conditions and circumstances.

Friere's methodology of teaching, curriculum development, and research can be schematically seen in three distinctive ways, namely, thematic investigation, thematization, and problematization. These are dialectically and interdisciplinarily intertwined.

### 2.7.1 Thematic Investigation

Thematic investigation is a process, which includes social research and analysis conducted by educators and representatives of the community for whom the curriculum is designed. In this process, investigators and participants get involved simultaneously. The investigators spend time in the community, participating in different activities. Through informal conversations, they assess and record people's experiences with the purpose of producing a comprehensive study of the community historical existence in all its aspects – social, cultural, political, and economical (Freire, 1970).

### 2.7.2 Thematization

The goal in this stage is to generate themes as well to determine the social meaning of the themes. Subsequently, themes are codified. Codifications are visual representations of specific situations familiar to the people of the community. Codifications become the program content of the curriculum of problem-posing education. Such education begins with the dissolution of the "teacher-student contradiction"(Freire, 1970, p. 67) in which the hierarchical relationship between teacher and student ceases to exist. The teacher is both teacher and student (and vice versa). Teacher and student come to know through dialogue, mediated by the world, which constitutes their object of study.

### 2.7.3 Problematization

In this phase, the generative themes are presented as problems to be solved or decoded. Here the participants attempt to overcome mythical views and achieve a critical view of their reality. In the process of moving between the real and the abstract worlds, they eventually return to the real world problematizing. Achieving a critical view enables people, student and teacher, to transform their beliefs and act upon their reality. The necessity to overcome the limiting situation, or the obstacles, is the key to the humanization process. Educating to be free brings a praxis of transformation.

## 2.8 Science Curriculum developed using Freire's Principles

In 1986, a research team in Federal University of Rio Grande do Norte developed a series of studies, *problematizing teaching in science.* The group wanted to test the application of Freire's principles in the creation of school science curriculum. The group decided to develop programs for rural and working-class urban communities following Freire's ideas used in the past to generate curriculum for programs, such us adult literacy, and health education.

Freire's approach was followed in the development of the science curriculum for the four grades of elementary school. In the studies a curriculum for the four grades of primary school was developed from the following *generative themes* (Figure 1):

*Living* was identified as the main theme, from which other themes were generated. Some of the themes were more related to social science than to natural science. Priority was given to the themes more directly linked to natural sciences.

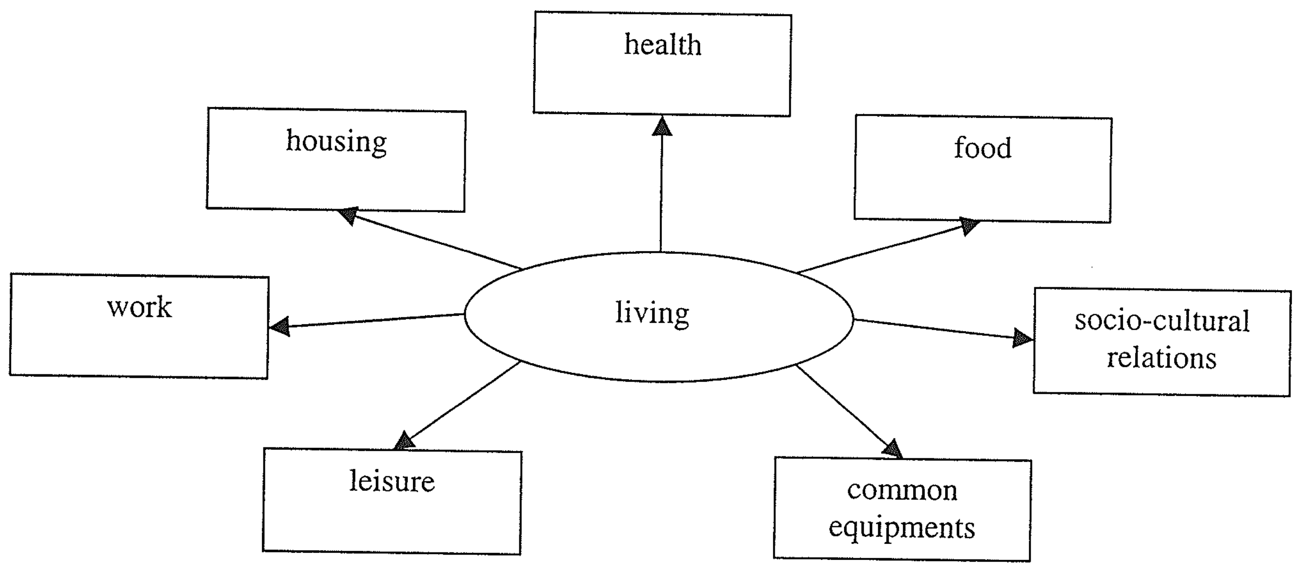


Figure 1. Generative teams (Source: Permanbuco et al.,1986)

From application of the three methodological steps (Thematic investigation, Thematization, and Problematization) a curriculum was generated for grade three students from a urban community (Figure 2):

The scientific topics explored in the curriculum, as well in the activities developed in the classroom, were developed in consideration with the structure of the generative themes themselves, the scientific structure of the knowledge and psychological development of the students.

Grade 3 - "I am capable of doing it. - The activities do also happen inside me".

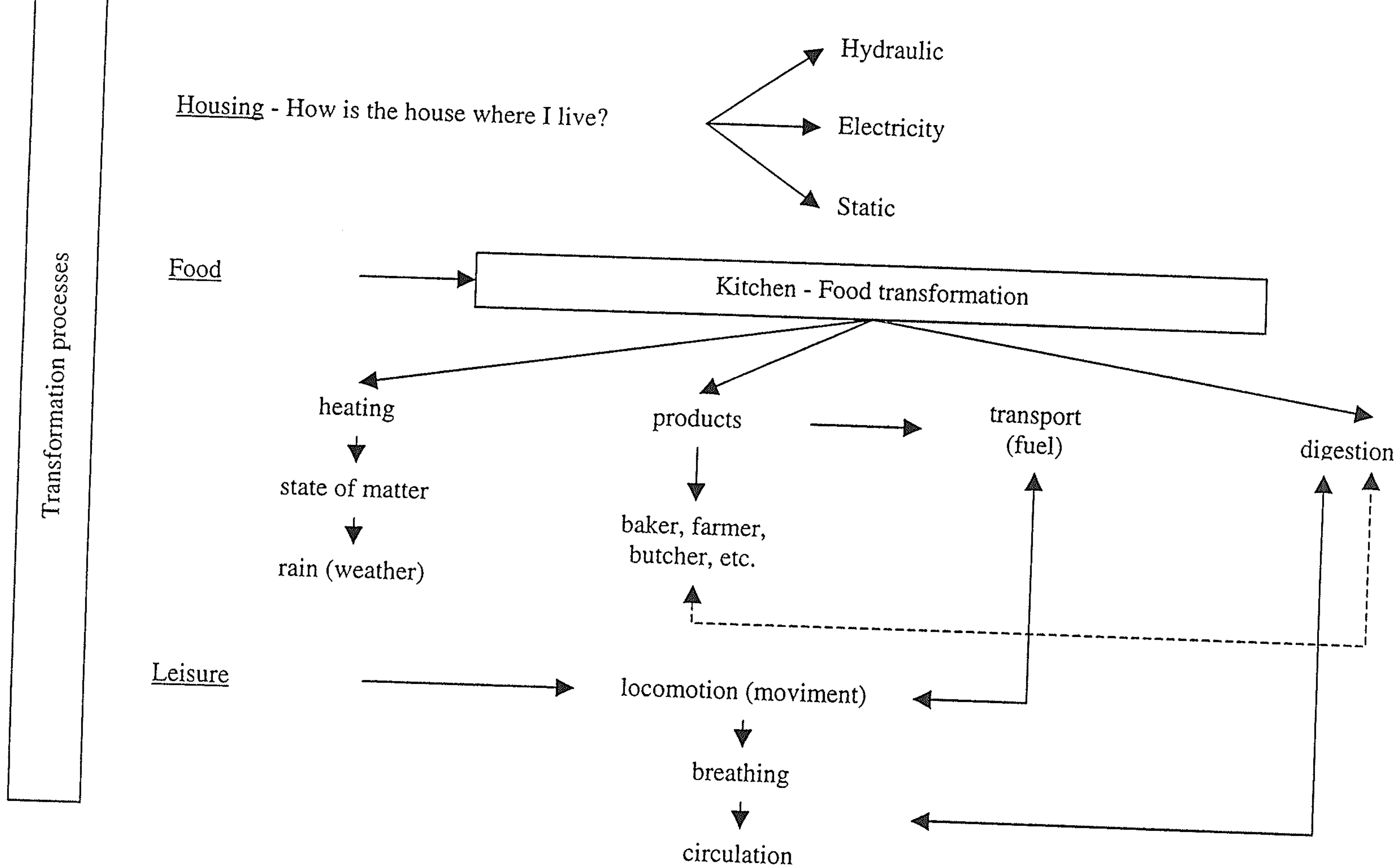


Figure 2. Science curriculum for Grade 3 (Source: Pernambuco et al.,1986)

## 2.9 Science Module Overview

The grade 3 and 4 seismicity module consists of a thematic approach (Dal Pian, 1993), which is advantageous in three ways. First, it relates science content to real life experiences and /or local problems of the community. Unit I examines the students' and community's initial views of the phenomenon of earthquakes. It also examines the citizens' aid and government's directions to control the situation. Finally it discusses students' understandings of the phenomenon. Unit II explores the perceptual aspect of energy transmission (e.g., mechanical waves). Unit III examines students' perceptions about materials' deformation and ductibility. Unit IV contains activities and a jigsaw puzzle to explore the Continental Drift and Tectonic Plates theories.

The second aspect of the module is that it describes the use of resources of process and content for thinking about scientific attempts to construct *rationality*. Unit I discusses important concepts, such as intensity and magnitude, energy and the Modified Mercalli Scale. It introduces the scientific view of the problem. Unit II focusses on the measurement of magnitude, thereby assisting the student to understand the process of energy release. Unit III, in presenting the plate tectonics theory, works with the geological models of the Earth. Unit IV examines the fault plaque as a plausible cause of earthquakes.

Thirdly aspect of the module is that it attempts to elaborate knowledge at an abstract level, making it specific at the experiential level. Unit I addresses anticipation of effects when certain conditions are under control. Unit II explores the transmission of energy without transmission of matter. Unit III conceptualizes seismicity. This unit deals with hypothetical content of the agents responsible for earthquakes: magnitude and intensity. Unit IV presents an explanation for the occurrence of earthquakes in João Câmara, as well as for other parts of the country, and the world.

All the units were developed using Freire's teaching/learning methodology. Thus the topics of each unit are enmeshed in three distinctive and intertwining *pedagogical moments* (Delizoicov & Angotti, 1990, p. 54-55): 1) study of reality, 2) organization of knowledge, and 3) application of knowledge.

Situations and/or questions are presented to the students for discussion in the study of reality. This discussion gives opportunity to the teacher to gather the kind of perceptions students bring with them to the classroom. On the other hand, initial discussion can cultivate in the students the necessity to acquire other knowledge, which he/she does not have. The role of the teacher in this moment is to ask questions, create doubts, and encourage the students to look for all possibilities to which the problem points.

Following the discussion of reality, scientific knowledge is introduced as another way to look at the problem. Scientific content is unfolded and concepts and relations are developed. Comparisons between different kinds of knowledge are made with the purpose of differentiating approaches understanding. This allows teachers to apply different teaching techniques to better address the kind of topic being developed, and the specific nature of the students.

After the topic has been scientifically studied by the teacher and the students, the gained knowledge is applied to the reality in which the students and teacher find themselves. In applying the knowledge, the class and teacher are able to further analyse their reality and to arrive at the best way in which to study and understand the topic.

## 2.10 Development of Science and Implications for Children's Conceptual Development

Through the development of human history, one can encounter different views, ideas, beliefs, and developments. These are the result of interactions among humans, of humans with the environment, of humans with artifacts, as guided by the necessities generated at a specific time and place. These interactions are mediated by human creative capacity to find solutions for the necessities that they encounter. This creative process of reflection and action is what mainly characterizes human beings (Ogborn, 1989a, 1989b).

With human development, and increased complexity of life, the process of reflection and action diversify, and two characteristically different ways of interacting with the world emerge:

The first is a more rigorous, analytical, and specialised reflection called science, which keeps telling us that the world is not always in reality what it seems to be (Macaskill & Ogborn,1996), and

The second is a more experiential, intuitive, and less specialized one, with commonsense taken to be constantly seducing us to believe that the world is exactly what it seems to be.

Nonetheless, one cannot exist without the other, because they are intimately intertwined, since both are the result of human reflection and action upon the world.

If one compares the development of children's conceptions with the development of science, one will find some points of similarities in the struggle to know. But one cannot say that they are the same because they function differently. Children's conceptual development is guided by a curiosity with the novelty in the exercise of one's senses. In this process, children are not assuming any obligation. They may or may not use previous experiences to approach the object of their curiosity, and they may or may not construct an explanation about the interaction. Scientific conceptual development is guided by a directive curiosity in the exercise of one's investigation of the world. In this process, scientists assume commitments with regard to theoretical, methodological, and goal/aim. Thus, there is always a kind of predicted hypothesized result from these interactions.

### 2.11 Epistemologic Obstacles in the Teaching of Earthquakes

Despite the interest and curiosity that the topic of earthquakes provoked among students, it did not help to eliminate the obstacles/difficulties for understanding the phenomenon (Monchap, & Sauvageot-Skibine, 1995). As in any other science, the history of geology shows periods of struggles for the development of its paradigms. As well, the human spirit, including the scientific quest, seems to be quite conservative in relation to changes in the way we understand the world. In science, as in any other area of human knowledge, developmental changes occur slowly. And because theories alone do not stand by themselves, unless endorsed by some kind of proof, theories can take decades to be accepted.

Some theories are conceived quit ahead of their time and must wait for technological development in order to be confirmed. This is the case with the development of geology as it now stands. The new view of the world that geology brings today is inherent to the Continental Drift Theory. Time, technological development, and research were necessary to build enough evidence to support the view of a *dynamic* earth in opposition to the *permanent* view which was dominant at the time of the original description of the drift of the continents by Wegener in 1912. Time, technological development, and research were necessary to build enough evidence to support the view of a *dynamic* earth in opposition to the *permanent* view which was dominant at that time.

As biology experienced a huge impact from Darwin's theory of the species, geology was tremendously affected by the presentation of *continental drift*, as well the *plate tectonics* theories. These theories necessitated a change in the nature of its object of study. Subsequently, studies assumed a global and holistic character as opposed to the local and isolated view which had previously dominated. The earth is seen, now, as a dynamic object, going through cycles, and in permanent change. With this change, a new idea of how we understand time and space has developed.These two essential concepts are topics which demand certain level of abstraction for the students, as well as teachers, for the understanding of geological events. Another element to be observed is related to the natural processes of mental development in children in the various ages, which will make it difficult, or sometimes impossible, for them to understand at that particular time the models of representation of the geological structures. On the other hand, there are the misconceptions, which are strongly connected to the nature of our cultural unconsciousness, and for this reason, are extremely resistant to change, even after years of education. Usually, students do not spontaneously express their own views about the world. Thus because they are not detected and worked out by teachers, they form an obstacle to the teaching/learning process (Allain, 1995).

Gabriel Gohau (1995) reminds us that children's development does not coincided with the history of the ideas, although the obstacles are the same. These obstacles include, limited knowledge and experiences, limited resources and instruments for seeking knowledge, and established views and/or common beliefs about reality. However, similarities end there. With regards to children's development, they have the natural limitations of their inherent maturational process, such as the development of language, thought, concepts, perceptions and skills. In time and under favourable learning conditions, children may mature making sense of reality. In the development of science throughout history, what one encounters is a cumulative process in which limitations are not of natural maturation; the limitations are more in terms of strategies, aims and interests of research, availability of methods and technology in means of proving ideas.

## 2.12 Summary

This chapter presents various aspects contributing to our understanding of the complexity of education and its job of conceptual change.

In the first topic, *Beliefs of earthquakes*, different views, which were developed from human experiences with nature, are presented to show how common sense conceptions can so strongly and deeply influence our perception and interpretation of our experiences in the world.

The second and third topics, *Historical development of the knowledge of seismology* and *Scientific explanation for earthquakes*, show a different view based in a more systematic approach of observation and interpretation of reality. This view is presented so that we do not rely only in our own senses. This systematic approach uses, in addition, a variety of instruments, strategies and devices to construct explanations about the world in order to develop a more inclusive interpretation of phenomena in the world.

The following sections, *The context of study*, and *Primary education in Brazil*, describe the setting where the earthquakes occurred, as well as the conditions required to observe the kind of view that dominates the people's interpretations of earthquakes.

In *Freire's ideas on education*, I present an overview of his view of what education should be: a continuous process towards human liberation, where men and women are able to fully participate in the construction of history. The general methodology developed by Freire to implement his idea of education, which is based on dialogue and problem-posing with the aim of empowering people in their struggle towards humanization, is also presented so as to provide the philosophical bases of the methodology employed in the development and implementation of the teaching of earthquakes in São Paulo do Potengi.

In the section, *Development of science and implications for children's conceptual development*, I return to the discussion about the different interpretations about the world, bringing into the discussion one aspect considered by studies in the area of children's conceptions and which seems to have started to dominate the discussion in this area, which is the argument that the development of children's conceptions is similar to the development of science. I observe this in this study where teachers' conceptions did not differ from children's conceptions. Furthermore, teachers had to deal ultimately with children's views of earthquakes.

In the section, *Epstemologic obstacles in the teaching of earthquakes*, I bring to the discussion some of the complex aspects of the scientific view used to explain the causes of earthquakes, which I confront with other elements which contribute to the obstacles found in the teaching/learning of earthquakes.

This chapter addresses the different instances where a discussion about the task of education in conceptual change should take place. It is very important to address the specificity of a problem in the attempt to solve it, but in doing so, it is imperative to observe its various implications in the broader picture in which the problem is inserted. In the present case, the apparent problem was the teachers' lack of knowledge about earthquakes. Looking from the surface, it was a very simple problem to be solved – as to teach the teachers about earthquakes. But, in having a closer look at the problem, one realizes that the problem will be far from its solution, if only the apparent and more immediate aspect was addressed. Therefore, it is important to look at the problem considering all its aspects: from its possible origin and nature, to its context implications and possible solutions, in order to have a effective outcome.

# CHAPTER III

## 3.1 Introduction

This chapter describes how empirical evidence was gathered to provide insights to answer the following research questions:

1. What were the experiences of the teachers in São Paulo do Potengi during the earthquakes of 1986?
2. How did teachers' perceptions and concepts of earthquakes change as a result of these experiences?
3. How did the seismicity module direct them in applying their perceptions and concepts for their teaching about earthquakes?

Because I wanted to understand the teachers' experiences of the phenomenon of earthquakes, and how those experiences affected their views of this natural phenomenon, and also, how their classroom practice was affected, I choose qualitative research methods for this study.

I wanted to understand how the events triggered the process of their conceptual changes. I wanted to gain a descriptive picture of how the process of conceptual changes occur in an attempt to identify the existence of stages or steps in which these changes may occur, or even the actual motivation for these changes.

## 3.2 Methodology

In order to answer these questions I was influenced by the ethnographic research approach, which offers, amongst other benefits, an opportunity for the social scientist to be able to adapt or create suitable aids or instruments for data collection. Data is collected allowing the researcher to construct a picture of a particular object of study. The ethnographic approach takes into account that human behaviour and the ways in which people construct and make sense of the world are highly variable and locally specific (Le Compt & Schensul, 1999). Considering such attributes, I designed an open-question interview protocol to accommodate the cultural characteristics of the participants, as well as to yield data to answer the research questions. Also, employing Freire's dialogical procedure I used the Science Module as the *code*, in order to present the reality that we were going to discuss.

My goal in this study was to establish a dialogue with the teachers where they could reflect on their own experience, their views, and their teaching practice with regard to earthquakes and how their experiences influenced their conceptual change. I also wanted to see if somehow they could perceive or identify how the changes occurred.

Besides the interview, I observed the teachers during the "Extension Course on Innovation in the teaching of science: Theoretical and Methodological Aspects". Notes were taken with the purpose of collecting additional information about the teachers' understanding of the phenomena of earthquakes, any change in their understanding, as well as to find out any concerns they may have about earthquakes.

### 3.2.1 Interview

The main strength of interview as a research technique is that it gives the researcher and participant an opportunity to explore possible meanings and interpretations about the subject being investigated (Punch, 1998, pp., 174-175). To enhance this technique I used group interviewing (two teachers in each interview), since that group interaction can stimulate people making explicit their views and perceptions of reality (Punch, 1998, p. 177). In presenting the questions or topics the role of the researcher here is to direct, facilitate, and record group interaction.

### 3.2.2 Participants

In my study, I interviewed nine school personnel, all females, aged 28 to 55 with 5 to 35 years of experience of working in schools by the time of the earthquakes ( In Brazil it is not unusual that most elementary school teachers are women). Seven of them were teachers who had a high school certificate with special training in teaching. This allowed them to teach from pre-school to fourth grade, and in this study, they specifically taught grades three and/or four. The other two teachers had university degrees: one in education and the other in social work. The one with an education degree is a school supervisor, working directly with teachers in matters related to teaching and learning, and school bureaucracy. The one with a social work degree is a school adviser, working directly with students in matters related to student performance, and well being in the school. All the participants worked in public schools in the São Paulo do Potengi area.

Immediately following the earthquakes in August 1986, three of the teachers were involved in the discussions on and development of the seismicity module from the very start. The other teachers were introduced to the material later on. For some of the teachers, this was the first time that they had participated in such an university extension course. They stayed full time in a facility where they had their meals, attended the course, and spent the night. For some of them, it was also their first time in a big city, and their first exposure to the research interview process.

### 3.2.3 Procedures

Permission to interview the teachers in the "Extension Course on Innovation in the Teaching of Science: Theoretical and Methodological Aspects", was obtained (see Appendix D) prior to my arrival in Brazil. Shortly after, I received a positive answer from them.

The extension course is part of the research approach adopted by the ESTU, which sees the relationship established in the research process with the participants as an opportunity for improvement and development of all the participants: researchers, coordinators, advisers, teachers, students and in extension the community. It is an opportunity to give back to society the fruits generated by the research process. In this way it does not stay relegated only to reports, papers, and a small group of people, the results are immediately transferred to the praxis.

In the course all participants have opportunity to learn/teach new things about the world. Course structures follow the educational methodology described in chapter II. It is usually held in a intensive fashion, where participants are gathered in one facility where everything is available and the possibility of both formal and informal exchanges is embraced.

Upon my arrival in Brazil, and after a few meetings with the group for the purpose of gaining information about the school personnel from São Paulo do Potengi, I realized that only a few teachers had confirmed their participation in the course.

On the first day of the course, I tried to talk individually with each of the participants to determine if they were interested in being interviewed. Because the course was designed to operate on a full day schedule, interviews were scheduled to take place in the evenings right after supper.

During this first contact and other encounters, I observed that the interviewees tended to stay always in pairs or small groups. I observed that the small group conversations were more relaxed than when interviewing individuals.

Interviews formed only a part of my work. To gather data for my study, I used three different procedures:

Initially, I observed the teachers' participation, in the activities of the Innovation in the Teaching of Science: Theoretical and Methodological Aspects course. During the lectures I took notes whenever teachers discussed the topic of earthquakes.

Secondly, I conducted group interviews with two teachers at a time. During the interviews, I asked questions about classroom conversation involving their experiences during the disaster and the development of the Seismicity Module, and about how it changed their views about the phenomenon of earthquakes.

Thirdly, using a concept probe, I asked the teachers whether or not a new activity on safety procedures ( see Appendix E) to be used in case of an earthquake should be added to the seismicity module, and if so, why and in which section it should be added.

My first research procedure was an exploratory attempt to find out how the teachers would articulate their ideas, what kind of questions they would bring to the discussion, and especially what kind of new information they would have acquired since they had started to study about the phenomenon. The second procedure was used to try to understand the organization of their particular views about the subject of earthquakes. In the third procedure I attempted to understand if their *new view* of earthquakes would enable them to make projections into practical applications to their lives.

The interview protocol began with a few basic questions, with the aim to motivate the conversation, as well as to collect the same kind of information from all the respondents. The interview questions were as follows:

1. What was the people's behaviour during the earthquakes?
2. What were the students' reactions to the phenomenon of earthquakes?
3. What is the importance of the Seismicity Module? (What are its positive and negative points?)
4. What kind of difficulties did you face when you worked with the module?
5. What is the central or most important concept in the module?
6. Did the module change your concept about earthquakes? Explain.
7. Are there more secure places than others where earthquakes occur? Where are they and why?

8. Let's suppose that you are in the classroom and an earthquake starts. What would you do? What would be your reaction? And after, if you had the chance, how would you continue the lesson?

The order of questions in the conversation did not always follow the sequence above. But the interview always ended with the suggestion of an activity to the teachers to be introduced into the module. Then I would ask the teachers, where in the module, an activity like this could be included. The last part of the interview was aimed to problematize the aspect of safety procedures in times of earthquakes which was not addressed in the module.

I did not predetermine which teachers would be paired for the interviews. The pairs were constructed according to the availability of the teachers on each particular day. Interviews took place in a room that was available each evening at the facility where the course took place.

All the interviews were conducted in Portuguese (see Appendix F) and recorded on audio tape, which were later transcribed and translated into English.

Before each interview took place, I explained to the participants my research objectives and assured them of confidentiality. It was explained that a pseudonym would be given to each participant, so as to ensure anonymity. Moreover, only brief and general information would be given about their background and their schools. The participants were further informed that their participation in the study was completely voluntary and that they could discontinue the process at any given time. After the participants affirmed their intention to participate in the study, I immediately commenced with my questions.

Following the completion of each interview, I asked each participant if there was any concern about the interview or if they would like to add or make any changes in any of their comments. Furthermore, I inquired about questions they might have regarding the study. Subsequently the participants were thanked for their time and contribution to the study. The length of each interview was approximately one and a half hours.

## 3.3 Process of Accessing the Data

Very early in my study, discussion notes and data were examined for their relevance to the development of the teachers' discourse. For example, when recounting their experiences during the earthquakes, the teachers always made use of some kind of description of the events (the earthquake itself, people's behaviour, or explanations for the events) in the construction of their statements. Their recollections were strongly tied to other people's behaviour, and rumours which dominated the themes of conversations at the particular time of the disaster.

I formatted the data in a way that allowed the teachers a chance to speak for themselves about their experiences, and express their views of earthquakes and the seismicity module. I introduce each part of the teachers' responses and conversations with observations of my own understanding of the teachers' accounts. I also bring into the discussion findings of other studies, which I hope will offer a broader perspective about each specific theme being presented in this study. I am using mainly findings of studies dealing with children's explanations since studies of adults' conceptions are limited. In the end, I pull together the points stressed in the prior sections to give a perspective of the role of education in conceptual change.

### 3.4 Limitations and Delimitations of the Study

The study is limited to teachers' experiences and conceptions, since it was impossible to locate all the students which attended school at the time of the earthquakes, because of high drop outs incidence and migration in the region.

It was not possible also, to interview a larger number of teachers, since migration and other factors made the task of locating other teachers very difficult, limiting the total number of interviews.

Since the interviews were conducted in Portuguese, transcribed in Portuguese, and translated into English, I was not able to share the original data with another scholar.

CHAPTER IV

## 4.1 Introduction

This chapter reports results from the interviews with primary teachers in Brazil for the purpose of examining their growth in understanding and teaching about earthquakes. The interview transcripts were analysed, observing the process by which the teachers developed their arguments. The interviews started by presenting the seismicity module to the teachers and asking them to try to remember about the earthquakes and their experiences with the seismicity module. The discussion provided data about (a) teachers' experience of the earthquakes, (b) misconceptions about earthquakes, and (c) views about the science module, as well as (d) some insights about the process of learning/teaching developed through the methodology used.

## 4.2 Teachers' Experience of Earthquake

The teachers' descriptions about their experience with the phenomenon of earthquakes show that they had not previously experienced this kind of event, and that they were immersed in the *social confusion*, which is common following such events. It also exposed their lack of knowledge about the phenomenon and their attempts to make sense of it and to integrate the new reality with previous experiences. These experiences were mainly related to the senses and sensations, as the following excerpts from the interviews illustrate:

> ***Susan:*** *I was not in the classroom that day. I had gone with Arthur to the bank. I had just come out from the bank when I heard ... it was a propane gas cylinder. It was a pressure cooker ... it was something else ... And nobody knew for sure what it was ...*
>
> ***Diane:*** *I was in the classroom at that time ...*
>
> ***Susan:*** *Then, they came and told us that it was an air plane. You know? ... Something like that ...*
>
> ***Diane:*** *Yeah, because it was Aviator's Week ... It happened on Friday. It was really a big one ... 'PAAAAAA' ... But, my students did not have any reaction. But, do you know why? Because they did not think that it was an earthquake. They, my students, thought that it was a fire that had burst ...*
>
> ***Susan:*** *Exactly, because also it did not seem ... because it was like ... 'POOOOUU' ... and that was it. The rumble, at least ... the ones that I had ... They make an echo like ... It lasted for some time ... when a quake happens, we can hear a noise that sounds*

*like ... 'UUUUUUU' ... You know? ... like an echo ...*

**Beth:** *There was an earthquake, it happened, occurred ... Do you know why? Because lots of houses cracked in São Pedro. To mention, my house, it was a new house and it cracked all over. The majority of houses, in the place where I live, you know Gina? All of them cracked, you know? Since that day, cracks appeared in my bedroom, in the kitchen, in the living room, and in the other bedroom. In my friend's house, the floor crunched from the front door to the back door, and the walls cracked.*

As in the first studies about earthquake, people try to measure its occurrence by the observation of physical damage noticed in the area. It is important also to observe that in the case of a disaster, such as one described in this study, emotional factors come to play a strong role in how and what people learn about the event, which will determine the kind of response they will provide in such an occasion.

As the excerpts from the interviews show, prior experiences play an important role in the people's perceptions of the event. People tend to make comparisons or relate present experiences to prior and similar experiences to be able to build an explanation about the new experience. Using the excerpts above as examples, Susan enumerates a few possibilities which were considered by the people at that time, relating them to her previous experiences with loud noises to try to identify the noise she heard that particular day. She also brings up the "official" explanation for the noise: it was an aeroplane.

Diane gives the explanation given by her students. Then Susan gives a few more details and compares the different noises. Beth describes the physical damage to the houses, including her own house, reasoning about a possible earthquake occurrence on that particular day. Every detail will play a role in the formation of their concept about the event.

Results of long term studies in human behaviour ( Takuma, 1978) in the events of earthquakes have shown that, because broadcasts may contradict what people are experiencing first hand, and because people immerse themselves in a state of confusion as a result of the event, one is more likely to trust and act on information received from people with whom one has direct contact. Consequently, whatever the information learned from these direct contacts become more important than information from other sources. Unfortunately, most of the time, this information proves to be only rumour, which tends to arise "when people are unsophisticated and are both anxious and neighborly" (Takuma,1978, p.169).

Teachers, in their accounts of earthquakes often emphasize people's behaviour during the events. Such is the case in the following excerpts:

> ***Judy:*** *There was a day when a very strong earthquake happened, that we thought the house was going to collapse. And we had to put mattresses, sheets everything on the side walk, on the ground to sleep, because ... afraid to go inside, to go inside the house, that the house might collapse, and we would be done for.*
>
> ***Susan:*** *The first [earthquake] ... like ... that we saw, felt. Not see, felt. It was like this ...BIG. And everybody was terrified. It was midnight, when a big one happened. After a while, people running to the side-walks. It was like ... But nobody went back inside the houses anymore. What I know is that some people stayed on the sidewalks. Some were lying down, others stayed sitting, and others stayed to talk with each other. And when it was almost dawn, around 5:00 a.m., another one happened. This one was even bigger. And the main*

*comments were this: One would call it a profuse river. Others said that it was a crater that opened somewhere.*

The conversations, interactions, and reactions to the events will be important to test their ideas about the phenomenon. Some ideas will be taken into consideration, some others will be tested, some others will be kept, and some others will be immediately discarded. The processes of conceptual change occur, and the ideas have been developed, despite the fact that the behaviour or actions will not reflect such processes. People develop their concepts through their experiences with the world.

The results of the studies described by Takuma (1978) indicate that strong emotional reactions and impulsive responses, such as fear and confused actions, such as people rushing outside without remembering, for example, to turn off the fuel outlets which they were using when the event happened. Such kinds of behaviour are predominant in case of earthquakes.

### 4.3 Teachers's Conceptions of Earthquakes

The teachers' conceptions of earthquakes show that they do not differ much from the conceptions of the students and the conceptions of general population in the area (See p.3 and Appendix 1). Despite their scientific knowledge, when they were faced with the unknown, their first natural impulse to make sense of the reality went towards their commonsense framework to the point in which they start to realize that this framework did not completely answer their questions.

> ***Joane:*** *They had the idea that at any time soon, one of the tremors was going to open a volcano, or something like that, in any place.*
>
> ***Susan:*** *One would say that it was a profuse river. Other said that it was a crater that opened somewhere.*
>
> ***Carol:*** *It is necessary that we also try to know to be able to cope better, to be able to understand that it is not God's fault, that it was not God who sent it, that it was not nature's punishment.*

Later on in the interview Carol offers the following explanation for the earthquakes.

> ***Carol:*** *When people asked me, I used to say, look, the only thing that I know about these booms is that some people say that it is a rock matter, ... ; other people say that it is a crack in the earth, but I cannot give you any information about it, because I do not know the subject. I only know that there is, it must happen, something strange there, inside of nature, there inside the earth that takes this*

*defect, this cause that affects  us today.*

The ideas presented above about the possible explanation for the occurrence of the phenomenon were also taken into consideration by the teachers at the beginning and were changed and polished as new information was available, as new concepts were introduced, as a new way of looking at and thinking about the earth was presented. We observed that many of those original ideas tend to persist to reoccur in the teachers' explanations about the phenomenon. Especially the ones related to the cause of the phenomenon. This resistence to change to a new view has been observed in other research.

Studies in other areas of  conceptions have shown that preinstructional views which students bring to the classroom tend to be persistent, and are highly resistant to change even after formal instruction (Osborn et al, 1983; Osborn & Gilbert, 1980). Evidence that adults also hold misconceptions about earthquakes can be found in Turner et al (1986). In their study, 1450 adults were interviewed in southern California, and according to the results many people believe in the existence of predictors, signals from nature which anticipate the occurrence of earthquakes, such us earthquake weather. There is also evidence that children hold misconceptions about other geological phenomena (Allain, 1995). Despite these facts, it seems that the area of children's conceptions about earthquakes is largely unexplored. I only was able to find one article, in the published literature, which discusses the subject. The article was written by Ross and Shuell (1993), and presents the results of three studies about elementary students' conceptions about earthquakes. Among other findings, the results of the studies show that children hold information about earthquakes prior to the formal instruction given at school. Also, that classroom instruction results, in relation to the acquisition of an understanding about the phenomenon or a reduction in misconceptions in a topical area, does not differ substantially from the ones in other areas.

One teacher describes how she tries to learn about earthquakes to be able to answer, at least, some of the questions that her students brought to class.

> ***Susan:*** *Because I did not have an exact answer to give to them. Then, I used to keep watching the news every day. I used to get the newspaper, trying to look for something. I tried to better understand it to explain to them [the students].*

Another teacher talks about teachers' difficulties in understanding the studies about earthquakes.

> ***Joane:*** *We were studying science, history, and the difficulty to know what was happening in the studies about this.*

Another teacher gives the following account for the kind of difficulty that she encountered:

**Carol:** *It was a subject, like ..., history of planets .... We got scared, but we did not have a complete explanation, because the science teacher did not give an opportunity. Because he thought that it was a subject exclusively for the geologists and the researchers from the university.*

**Diane:** *The material about water and drought, or the one about agriculture, something like that, but everybody feels that in their skin [as part of their daily experience]. And the earthquakes are ... They are not something that happen like this. With time: Suddenly stops and suddenly starts again. It is something that, even the studious, the scientists, could not figure it out yet, why things happen. Because there is not an exact explanation of this. Now agriculture, not, the agriculture we can see, it can be practiced by us.*

These excerpts provide a good picture about how people establish priorities in terms of what to learn. It is easy to learn about things to which they have a more immediate relation; it is present in their daily experience. Other things, events, or subjects which have not a more constant presence in people's lives do not represent a priority to be learned. And because of this *distance*, they naturally have difficulty in learning about them. The excerpts also show how people establish divisions and hierarchies in terms of who should learn/know about what. They also, shows that the language used in science is different from the language used in daily life, and further, the means and instruments by which the knowledge is produced are not available everywhere and to everyone.

Ross and Shuell (1993) argue that probably because of the non-observable nature of the idea currently accepted in science to be the cause of earthquakes, which requires of one to believe that "large chunks of rock move unseen, and unfelt beneath"(p. 202) one's feet causing unpredictable and sometimes destructive events, may make difficult the understanding of the causes of earthquakes by children and adults.

Some of the teachers acknowledge their lack of knowledge about earthquakes.

***Susan:*** *I did not know almost anything.*

***Judy:*** *I used to hear people saying: earthquake, ... earthquake, ... And ... I did not know the causes, ... I only knew the effects caused by it, but ... the rest ... I did not know where it came from, how, and from where it originates.*

Facing so many difficulties and not satisfied with the kind of information available, the teachers decided to look for more accurate explanations, as one teacher points out:

**Carol:** *The position in our school was different. Our concern was to know, to discuss the subject, because then it was the responsibility of the people.*

4.4 Teachers' Changing Conceptions and the Seismicity Module

A team of professionals and the teachers developed a Seismicity Module, following Freire's principles. The teachers have a very positive opinion about the module. They believe that the seismicity module itself is responsible for the changes that occurred in their views and in the students' conceptions about earthquakes. The following transcript excerpts will illustrate this point.

**Carol:** *With the material we were able to see differently the subject, to understand that earthquakes are part of the nature of our planet. It is not something far from our daily lives. And we need to learn how to live with it.*

**Joane:** *After they[students] started to study that material which explained better what it was more or less, what an earthquake is, they started to become calm. They could feel the earthquake, they could feel the tremor, but they were calm. Because they were able to understand better what it was that was happening.*

In another excerpt, Joane gives a brief description of what kind of activities were developed in the process of making the seismicity module, as well as in the teaching/ learning process developed in the classroom with the students:

> ***Joane:*** *We did a study of the reality [the events of earthquakes]. We started to work with simple materials, very simple materials, from which we could understand better, what it was that was happening. Showing, for example: showing with a spring the transference of energy that occurs alongside as well as across, showing the spring movements as energy. And through maps. Lots of things were used, obtained from people in the community.*

This excerpt shows how the researchers together with the teachers engaged themselves in the process of knowing the reality and discovering generative themes from which the content can be unfolded. The same methodology is used in the seismicity module and in the classroom with the students (an organized description of this methodology is found in chapter II). It seems that the teachers were convinced about the seismicity module as being the only cause of the improvement of their knowledge on earthquakes. Maybe this understanding can be explained by the fact that, before the seismicity module, there were no other comprehensive materials or other reliable source of information available in the city. Another explanation for this is that teachers were still immersed in their reality and were not able yet to perceive how the knowledge about earthquakes, which they now hold, was built.

On the other hand, teachers were able to voice and identify their difficulties in understanding earthquakes.

> ***Diane:*** *When we started to teach, to talk about this with the students, we experienced difficulties because we did not have deep knowledge about the subject.*

The teachers also tried to relate their previous experiences as students, with the aim of putting into perspective their limitations and difficulties in relating academic content with reality.

> ***Carol:*** *For example, I took an economy course in the faculty and I worked with topics. I answered I did the exams I passed successfully Understood? I got good grades, but I only was able to understand fully the meaning of the words used in economy at the time when they were worked on in a practical way. At the university I could not see any relation of this with my profession as a social worker. By the time I graduated, it was the 'dark time', the 'revolution' [referring to the military coup d'état that occurred in Brazil in 1964], debates were not allowed in the classrooms because it was in debates that we could learn about the reality of lots of people. So, the orientation*

*was to study, and always individuality was very strong in that period.*

This excerpt describes how education was in Brazil during an oppressive time, in which the military were in the power. The military took over the control of the country in 1964 through a coup d'état and stayed in the power until 1982, when federal elections restored the power to a civil president elected by the people.

The description given by the teacher about her own experience when she was a student at the university can also be related to the kind of education, which Paulo Freire strongly criticised and opposed. He called this kind of education "banking education", because it resembles the act of one depositing money in a bank. In such education, the teacher is considered to be the owner of the knowledge, while the students are mere receptacles into which the teacher deposits the knowledge. It is against this monological kind of education that Freire's dialogical method stands. In dialogical education, students and teachers are seen as "equally knowing subjects" (Freire, 1972, p. 31), making the dichotomy of teacher and student disappear. The teacher becomes the students' partner as they engage together in their quest for "humanization", where the teacher does not only teach, but also is taught in the dialogue with the students. In this way teacher and students are both equally responsible for the process in which all of them grow (Freire, 1972, p. 53).

The teachers in this study started to become aware of the differences between these two kinds of education and their implications for their lives. These differences can seem obvious for one, but they are not for the ones who are immerse in the world. It is only when one engages oneself in the continual experimentation of thinking and doing that one will be able to look critically at the world and start to transform reality.

### 4.5 Insights into Learning/Teaching

In analysing their experiences, the teachers give us some insights into what was important in their experience in teaching/learning about earthquakes and the processes involved.

> ***Judy:*** *I think that it was very important due to the debate. How we discussed. Then, we learned from that.*
>
> ***Carol:*** *Because it was built exactly with the information that we provided. Understand? In a debate, in a discussion we, as well as, the students. Then all these materials today, they mean something that really exists, that evolves and has a more scientific form. But it must be. Understand? Science, as much as, tries to speak in a more simple way. It cannot come down from the level of science. It*

*must help to guide common sense that is present in the things.*

In the discussions which took place during the Extension Course on Innovation in the Teaching of Science, the teachers also point to the direction in which their interest in the study of earthquakes had shifted. They brought into the discussion the fact that earthquakes have started to occur in another locality, São Rafael, in an area where a dam has been built. They also spoke about the dangerous consequences for the region if the dam's walls could break as a result of an earthquake. According to the observations made by the teachers, at least three cities could disappear under the water that could be released under the circumstances. The questions which were raised by the teachers deal with human interventions in nature, and if science enables humans to have such knowledge about nature's processes, why humans insist in challenging nature's forces. In their words:

> "*If they knew about the existence of a geological fault in that specific place and the possible consequences that it could bring, why have they decided to build exactly there?*" (An excerpt from a teacher's speech during one of the sessions of the course).

The other hint offered by the teachers about the shift in their interest in earthquakes can be illustrated in the following discussion between one of the teachers and me:

**Carol:** *As these earthquakes ended, diminished, it also did not constitute for us the main subject, or for us to worry about it.*

**Elíude:** *But now they are coming back.*

**Carol:** *Yeah, now they are coming back. There are the São Rafael earthquakes.*

**Elíude:** *But, also in João Câmara.*

**Carol:** *Yeah, somebody[a scientist] has already register [an earthquake] in João Câmara, only that it did not reach São Paulo do Potengi, but already somebody felt this.*

Tributsh (1993) presents a variety of studies which show a link between the storing of water and the increase of seismic activity in the area. This phenomenon was discover in 1945 by Carder, an American seismologist, "who described how the filling of Lake Mead in Colorado turned an earthquake-free area into an active one with quakes of magnitudes as high as 5" (p.177). After this discovery, much research has been done to find an explanation for earthquake-generating effect of the damming of water. As far as those theories can explain, there are two main mechanisms, which are responsible for the phenomenon: one is "the mechanical tensions released in the substrata by the weight of the water, which can cause movements of rocks", and the other is "the rising water pressure in the water-logged tiny clefts and cracks, which also has a kind of lubrificating effect" (p. 177). However, accounts of the correlation between earthquakes and storing of water, according to Tributsh, can be found over time and in different cultures. For example, Aristotle (348-322 B.C.) believed that "eatthquakes were stimulated by alternating saturation and drying out of the earth" (p.178).

## 4.6 Conceptual Changes

To conceive of a teaching methodology which differentiates itself from the informative posture assumed by the traditional education involves an understanding of what happens with the subject from the cognitive point of view in the process of knowledge expansion, when the general ways of understand and acting upon the world is modified. In other words, it involves a comprehension about how knowledge reorganization occurs.

When we think about such a methodology of teaching, we are starting from the understanding that there are different ways of learning, and that there are information and concepts which appropriation, in fact, imply in more significant modifications in the thought structure of the individual.

Nowadays with the popularity of the constructivistic ideas in education, it is very reasonable for us to arrive at such a position. On the other hand, it is not so simple to find how to make such changes occur. In fact, with respect to the more generic aspects of the learning process and in consequence for the study of the acquisition of specific knowledge, there is still not a consensus among researchers on how concept formation, or knowledge reorganization occurs.

Because most of the research in this area has been done with children, I will analyse Thagard's (1993) approach, which looks at the problem of conceptual change integrating cognitive and social explanation by using a framework from artificial intelligence to analyse the question of conceptual revolution in science, to look at the points which the present study addresses.

The first point which is important to observe is the idea of how knowledge grows. As for the scientific knowledge, if one looks at the history of science, one can observe that, in general, knowledge grows slowly with gradual additions and modifications with the introduction of knew laws and concepts. And that in some occasions science has experienced dramatic conceptual changes "when whole systems of concepts and laws are replaced by new ones"(Thagard, 1993, p.3), which become known as "scientific revolutions" (Kuhn, 1994).

Generally looking at the learning development process which a person undergoes throughout his/her development in life, one cannot refrain from trying to use such an analogy. As in science, a person also develops his/her concepts slowly and gradually adds and modifies his/her body of knowledge when introduced to new concepts and ways of thinking.

What one should be clear about, in the case of people's thought construction, is the fact that such changes cannot often be detected, since for the most part of what we learn and think we do not communicate to others and that such changes occur without a person's awareness.

It is also important to point out that ordinary learning cannot be seen as simple accumulation of knowledge, and it may not occur in such a revolutionary manner as occurs in conceptual revolutions in science.

As different levels of change can be found in science, they probably also occur in a person's knowledge. Although science has a kind of direction with respect to the development of knowledge, its development also faces obstacles. One cannot say that a person has the same kind of direction as found in science, but a person's knowledge development also often faces similar kinds of obstacles. For example, the lack of specific knowledge or an artefact will become the obstacle for the development of certain concepts. As well, there are beliefs which are important because they are deeply rooted in a large number of other beliefs. Other beliefs, which have a close relation to our personal concepts of the world, can constitute an obstacle for the development or acquisition of a new concept.

As far we can see, the task given to education is not an easy one. Education should be the means to communicate such changes (among scientists) and to help people learn to think, incorporate, and operate with the new system.

The kind of data provided in this study do not offer substantial evidence to make comparisons with the findings of Thagard's study. But from the information that was gathered, it is possible to see the need for more studies in the area.

I am convinced that a person does not experience the same kind of scientific revolution as occurs in science, but I am also convinced that, to some extent each person along with his/her development experiences some main conceptual changes which lead to important concept reorganizations. Those changes probably do not constitute a big event because the processes of ruptures, changes, and reorganization take a considerable amount of time to occur, and they are immersed and attached to other processes. It does not occur only in respect to one single area or concept in isolation, but it occurs in a broader and intertwined way.

I have tried to give as much information about what the teachers faced, how they dealt with the problem, and how their conceptions changed. As well, I tried to add information from other studies which have examined people's reactions to earthquakes, and to the matter of conceptual change which presented different perspectives. Although at first it can appear a little confusing, the intension was to explore the complexity of conceptual change and how difficult it is for education to do its job.

This study does not begin with the data collected and does not end with the findings presented. It is just a brief reflection upon the process which did not start with the earthquakes, nor ended with them.

The teachers and the people in general had their concept about the world and how it worked prior to the events of 1986. In a course for the teachers in the summer of 1998, their concepts of how the earth is inside came to the surface. They believe that the earth is round and that we live on its surface. Under the ground where we are, houses and buildings stand, and plants grow and animals live, there is a layer of soil and rocks and underground rivers (which are conceived by the theachers to be the same as the rivers that we see in the surface of earth). Below this layer what they imagine is the existence of an enormous hole, described by them as a big cave where there is water or lava (See Appendix 3). This conception of how the earth is inside does not differ much from the concepts presented in the writings of the ancient Greeks. Probably the teachers would have kept this conception or a similar one for the rest of their lives if the earthquakes had never happened and had not motivated them to ask themselves questions and look for answers to those questions.

The education methodology used not only allowed the teachers to find out new concepts about the earth, but also to experience and to learn more about their surroundings and how they can extend their knowledge and experiences to other situations.

The process takes time. The teachers have not yet completed their conceptual revision. They are not yet using in full the theory of plate tectonics to think about the earth. Nevertheless, in their accounts they have manifested evidence that they have started the process of changing their views about the world, and that the world it is not always what it appears to be – that there is more than what our everyday experiences can provide us.

According to Thagard (1993), a conceptual change goes beyond belief revision when it involves the addition, deletion, or reorganization of concepts or redefinition of the nature of the hierarchy (p.36). It is my understanding that the teachers to some extent are experiencing some kind of conceptual change specially in relation to their ideas about the world. Like the scientists, the teachers will have to mature the new ideas, experiment and learn to think with them. But the conceptual revolution may not happen for them as described by Thagard (1993) as a complete replacement of whole systems of concepts (p.11), nor occur in the fashion of scientific revolution, since the community as a whole will not adopt the new conceptual system (p.50).

From the teachers interviews, I can say that the process through which they are going is similar to the process of the acquisition of a new language. Once one is able to internalize its rationale, translation and vocabulary acquisition constitute only temporary impediments to its full use. In the case of concept acquisition, once one is able to think using the concept, transposition and definition/communication are only temporary obstacles to its full application (Thagard, 1993).

# CHAPTER V

## Summary, Conclusions, and Recommendations

This study documents the experiences of São Paulo do Potengi primary school teachers with the earthquakes and their attempts to learn about them, to be able to answer their own questions about the phenomenon, as well to teach the topic in the classroom and answer their students' questions about the occurrence of earthquakes in that area. Therefore, I began this thesis by introducing the phenomenon of earthquake from the perspective of a disaster, since it is through its effects that earthquakes have challenged people to look for answers for their causes since prehistoric times. For example, before measurement instruments were available, earthquakes were qualitatively classified according to peoples reactions during the events and by physical damage observed in the area ( Levy & Salvadori, 1995). Precisely it was this same factor, which lead the teachers to look for answers, since the explanations available in the community did not completely answer their questions as it is described in the section *Earthquakes in João Câmara* (Chapter I, p.3 ).

In addition, this study provides a broader picture about people's beliefs about earthquakes, as well the development of scientific ideas about the topic and its implications to teaching and learning about the phenomenon. This study examines the methodology used by the teachers in the development of the Seismicity Module to learn and teach about earthquakes. This methodology started from the understanding that education should prepare the student to fully participate in the construction of knowledge, problematizing his/her reality through dialogue (Chapter II).

Two different ways of perceiving and interacting with the world received attention in this study: one way is science and the other is commonsense. For example, science shows that earthquakes happen all the time and everywhere, in fact, somewhere in the world two shocks are recorded every minute (Kulhánec, 1990), while teachers, from their experiences, believe that the occurrence of earthquakes in their area is concentrated during the hot season. The aim was to emphasize that they are framed in different ways of perceiving the world, and both ways are present in the classroom.

The analysis of the data generated four main themes: a) teachers's experience of earthquakes; b) teachers' conceptions of earthquakes; c) teachers' changing conceptions and the Seismicity Module; and d) insights into learning and teaching. These themes were examined in Chapter IV.

This study examined the conceptual change in a group of teachers, aiming to gain a descriptive picture of the process.

## Conclusions

This study found that, despite the fact that teachers had not previously experienced an earthquake, they held previous conceptions about the phenomenon, such as: earthquakes are the result of God's power, earthquakes are cause by a dragon. Those conceptions are part of their core concepts about the world and how it works. Although those conceptions had never been used or tested by the teachers, they already existed in their minds. The conceptions had not been challenged by instruction. Because with these conceptions (or misconceptions), they were able to solve the simple and most immediate questions about their reality.

Furthermore, data also revealed that the concept of earthquakes is part of a core of concepts that are highly resistant to change (Gunstone, White, & Fenshan, 1988; White & Gunstone, 1989; Ross & Shuell, 1993). Possibly because the concept of earthquakes is deeply rooted in their view of the earth's structure and in their world view. The scientific view of the earth and its natural phenomena contradicts the commonsense belief that the earth is our home and, as such, is a stable and secure place (Ross & Shuel, 1993; Ogborn et al, 1996), constituting a crucial obstacle to the understanding of the phenomenon of earthquakes.

It was in trying to make sense of what it was happening when the earthquakes started, in trying to answer new and more precise questions about their reality, in analysing new information about the situation, that the teachers realized that their conceptions were insufficient to explain the events. The new reality challenged the teachers and gave them the opportunity to look for more information, a new way of thinking about the world, the development of new concepts. For example,

> ***Joane*** states: *an earthquake is an electric discharge caused by energy accumulation in the subsoil. The occurrence of an earthquake depends also on the climatic season. Earthquakes occur in the hottest season of the year. Right now, after the summer has arrived and there is an increase on the temperature, a strong [earthquake] one already happened.*

From those observations we can draw the conclusion that conceptual change occurs when people become dissatisfied with their views and they find new and satisfactory ways to look at the world (Posner, Strike, Henson, & Gertzog, 1982).

Another important finding is the fact that people will not become dissatisfied simply because something goes wrong or does not work properly. A teacher's explanation in the classroom does not convey levels of dissatisfaction towards an immediate conceptual change by his/her students. For dissatisfaction to occur, the existence of a strong and compelling motive is necessary. This motivation I call a *provocative* *agent*. The *provocative agent* launches a question, which cannot be answered by the concept held by the person at that particular moment. The *provocative agent* must be sturdy and must hold something special which was lacking previously (such as in school content, in books, or in life events). The *provocative agent* will not necessarily work in the same way or it will not have the same impact for everybody in terms of unleashing a conceptual change.

In the case of the teachers interviewed in this study, they had heard, read, and even discussed about earthquakes before, but the earthquake events had always happened in far alway places. A conclusion that can be drawn from this fact is that the earthquakes themselves, their consequences, and the unexpected occurrence of earthquakes at home constituted the *provocative agent* responsible for the initiation of the teachers' conceptual changes.

In the case of earthquakes, the lack of information about previous events in the region and also the lack of knowledge of the occurrence of earthquakes in Brazil added to the impact caused by the unexpected events in their lives. As a result, the new reality itself posed as a problem to be solved. A real necessity to understand what was happening and why, was created in teachers' minds. This necessity was reinforced externally by their students' questions and later in the discussions and subsequently the development of the *Seismicity Module*.

In their investigation of the historical aspects of the problem in that particular area to determine the sequence of the content of the module to be developed, teachers found themselves rediscovering familiar objects of their reality such as stones, mountains, and other geological formations. In this process, such objects gained a different meaning in their reality. Teachers were able to relate their surroundings with topics discussed in books.

After the themes were generated for the development of the science module, the participants were able to rethink their reality and to experiment a new way of looking at this reality. Although the scientific explanation presented did not at once replace their previous model, it was considered to be consistent enough to encourage them to make adjustments in their way of thinking and slowly incorporate the new concepts into their explanations. For example, as Joane and Carol explain:

> ***Joane:*** *We did a study of reality [ See Chapter II]. We started to work with simple materials, very simple materials. Showing, for example: demonstrating through a spring the transference of energy that used to occur alongside as well as across, showing the spring movements as energy. And maps. Lots of things were used. We gave seminars, we did interviews ...*

***Carol:*** *They [the students] started to see themselves different. That you do not have to be a geologist to be able to understand .... It is necessary that we also try to know to be able to cope better, to be able to understand that it is not God's fault, that it is not God who sent it, that it is not Nature's punishment. You understand me? We did not have this kind of information before. But with the module, we were able to see differently the subject, to understand that the earthquakes are part of our planet's nature. It [an earthquake] is not something far from our daily lives. And that we need to learn how to live with it.*

The teachers' roles in the development of the module as active participants of its making helped them to rethink the reality, reorganize their knowledge, and incorporate new concepts into their world view. However, it should be made clear that the conceptual change examined in this study did not happen in a straightforward, linear process such as: teachers' dissatisfaction with explanations available about earthquakes, followed by teachers finding plate tectonic theory as a satisfactory explanation for earthquake phenomenon, leading to a restructurization of teachers' core concepts, and concluding with the teachers incorporating in full plate tectonics theory into their world view.

What appears to have happened is that teachers accepted the main idea that earthquakes are not, for example, a result of God's acts nor the power of an angry dragon. Because these ideas did not satisfactorily answered the questions posed by the earthquakes.

Following this acceptance stage was a period of trials, where concepts attached to the main idea were examined and, if possible, experienced.

Although they seemed to understand the main idea that their explanations were contradictory, they used prior concepts along with new concepts. In most occasions, prior concepts contradicted new concepts. But teachers did not seem to perceive such contradictions. The impression is that teachers found a way to make contradictions work. For example, in these statements from teachers in a discussion during the Extension course:

*"Earthquakes can be caused by bodies inside the earth."*

And.

*"Energy is a force. Every body has energy but not every body has force".*

As time went by and teachers had many opportunities (which can be found in our day to day experiences, such as, a new event, a question or problem brought by a student to the class, a discussion) in their lives to experience the new concepts, the new concepts became more clear and present in teachers' explanations.

Concepts which can be easily demonstrated and experienced were the ones first incorporated to the teachers' world view. For example, the concept of ductility of the rocks can be easily demonstrated through simple experience, such as, trying to bend different materials collected to see which one easily breaks. On the other hand, concepts which require abstraction and cannot be directly experienced take a fair amount of time and require specific activities to be incorporated, for example, the concept of energy.

Furthermore concepts which are rooted in cultural and religious beliefs are highly resistant to change because they are part of a particular framework – world view – which frames peoples perception of reality (Taghard, 1993; Bezzi, 1994; George, 1999), for example, the earth's structure.

Despite the fact that teachers were able to teach about earthquakes and explain satisfactorily concepts to their students, they did not incorporate all the new concepts into their world view. Results from the third procedure (See Chapter III, p.55) used in this study indicates that apparently teachers were not able to see the connection between the knowledge about earthquakes and the activity about safety procedures to be incorporated into the Seismicity Module. The fact that teachers experienced the effects and learned about earthquakes somehow did not provide them with enough background to translate the new knowledge into practical applications in their own lives. Probably this is due to the fact that people unconsciously make differentiations between school knowledge and daily life experiences.

## Recommendations

The findings of this study suggest a need to obtain richer and more detailed accounts of people's conceptions about the world, such as, about earthquakes. Perhaps longitudinal studies should be carried out with the aim to capture the nuances of the process of conceptual change. The relevance and urgency of this kind of information can be framed in the main challenge of the current view of science about the world. Teachers and learners need to move from a conception of the earth as being a stable and permanent home to a new and unsettling view in which the earth is active. For example, thousands of earthquakes are recorded every day, in fact, two shocks every minute, according to Kulhánek (1990). The world is moving under one's feet (Ogborn et al, 1996).

Results also suggest that there is a need for understanding the implications of world view to conceptual change. For example, the idea to perceive the earth as an active and evolving object seems to impede people from accepting concepts related to the causes of earthquakes. People seem to have a need to point out an external power responsible for the occurrence of earthquakes. Perhaps, research should concentrate efforts in understanding cultural, religious, and language implications in the development of world views.

Implications for curriculum planning include using of contextualized information in contrast to a context-free approach. Materials to be applied in the classroom should make reference to actual events and contexts which are familiar to the students. In this way students will be able to relate to the topic being studied. Subsequently other contexts and more general information should be introduced into the discussion, providing the students instruments to understand the topic in a broader context.

Teachers should be able to identify students' preconceptions before presenting a scientific view. Students' preconceptions should be treated with respect (Ebenezer & Connor, n. d.), and the scientific view should be presented as another way to see the world, instead of the only correct one (Ebenezer & Erickson, 1996, Linder & Erickson, 1989, Marton & Booth, 1997). In this way students will have a better reaction and will be inclined to consider and use the scientific view. It is important to level the status of the two different kinds of knowledge because it will stimulate curiosity towards scientific view, as well as discarding the label of student knowledge.

The scientific view should be framed in its historical development, so that students will be able to relate their own struggles in understanding the world with the struggles faced by the people who were able to think a way to understand and put together an explanation for the matter before them (Stinner, 1992, 1995).

Students should be able to perceive themselves as active participants in the creation of knowledge, because it is in rethinking and reinventing concepts of reality that students will be able to learn about the world.

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Appendixes

## Appendix A

Explanations about Earthquakes

At 80 years of age and with 45 years of living in João Câmara, the farmer Marcos de Oliveira declared that when Father Cícero do Juazeiro once was questioned by his neighbour about the quakes which were happening at that time in João Câmara, his advice was: Pray to Nossa Senhora das Dores and ask God forgiveness for your sins, because the quakes are only the tide's movement.

(Translation from article published in O Poti, September 06 1986)

In an attempt to explain the many earth tremors which happen every day in Palhano, the 55 year old farmer Walter Rodrigues do Amaral gives the following explanation for the phenomenon: "There is, in our region, an enormous dragon, which measures more than 50 kilometres. Its head is settled in the Itaiçaba region, its tummy is asleep in Palhano, and its tale is among the Quixadá mountains." Very convinced of his explanation, this ex-miner from Teófilo Otoni defends it: "This dragon will, one day, cause big damage in our region, because when it wakes up it will not leave any dam in the area, such as Santo Antonio de Russas, and Orós." According to his theory, the region will be once again: "a big sea, as it was millions of years ago."

(Translation from an article published in O Estado de São Paulo, March, 11 1989)

# Appendix B

SEISMICITY MODULE

**Table of Contents**

Reading Materials

Reading 1. Human Action and the Energy Use by Luís Carlos Menezes et al. (1986)

Reading 2. Rocks Inside the Earth

Reading 3. Knowing the Earth by Carlos Nereu de Souza (1987)/ Reviewed by Marieta C. do Nascimento & Rielva S. C. do Nascimento (1992)/ Elíude S. Cavalcante & Rosemberg G. de Lima (1995).

For further information: Education Science and Technology Unit, Department of Education, Universidade Federal do Rio Grande do Norte, Natal, Brazil.

# Appendix C

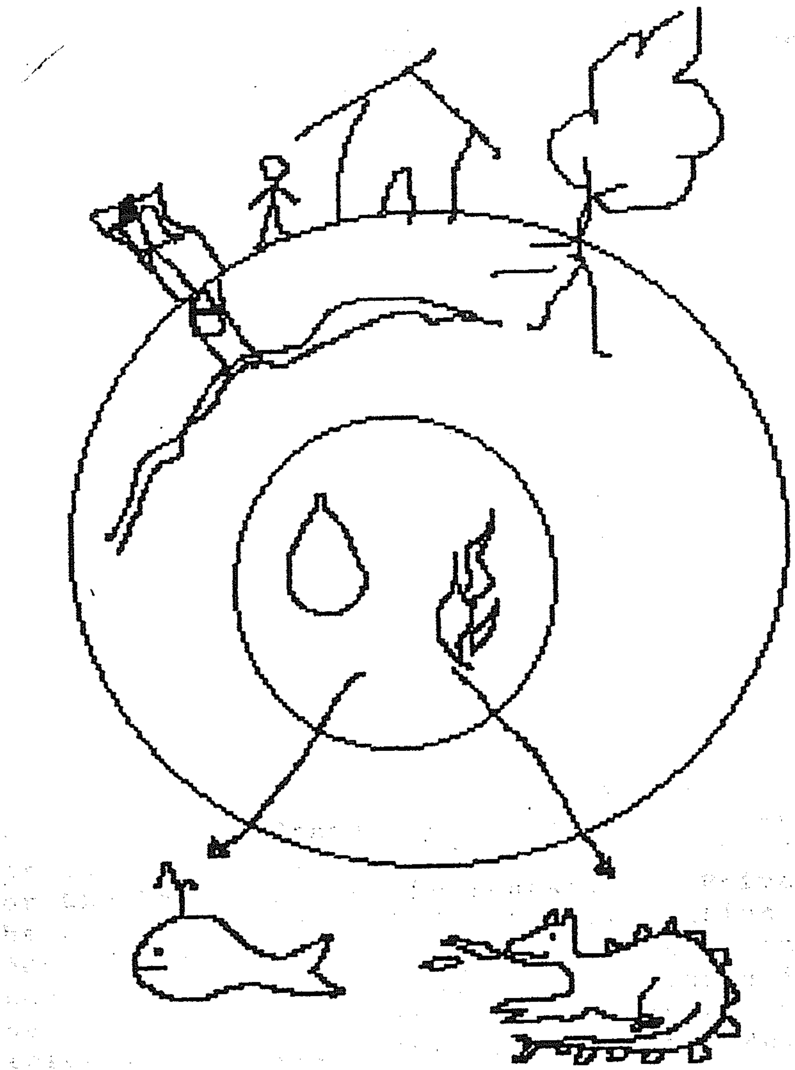
Teacher's Model of Earth Structure

During one of the sections of a course for the teachers in the summer of 1988, one of the teachers started question about how the earth was inside. The researcher, who was directing the section, asked back the question to the teacher, and subsequently asked for details during the teacher's description of how the earth was inside for her. A very intense dialogue was established with the participation of all the teachers in the room. A sketch was drawn in the black board (Which I reproduced here from my notes of the course).

According to the teachers' description, the earth is round, and we live on its surface. Under this surface there is a layer of soil and rocks, where underground rivers exist and operate in the same manner as they do on the surface.

After this layer there is a hole, or big cave. Up to this point they all agree with the explanation, but they disagree about the description of what can be found inside the cave. Some defended the existence of water and others defended the existence of lava, since there are many volcanoes on earth.

I have also included, in my sketch of their explanations the two most common animals (dragon and whale) found in the explanations given by the students about what causes the earthquake.



MINISTÉRIO DA EDUCAÇÃO
UNIVERSIDADE FEDERAL DO RIO GRANDE DO NORTE
ASSESSORIA PARA ASSUNTOS INTERNACIONAIS

The Review Board
University of Manitoba
Winnipeg - Canada

Dear Sir.

The Institutional Review Board of the Universidade Federal do Rio Grande do Norte has reviewed the application for data collection of Eliude Silva Cavalcante's research for the Master Degree in Education - University of Manitoba. The plan of visit includes the evaluation of the "Seismicity Module" used by primary school teachers in São Paulo do Potengi - RN/Brazil and three-weeks course intended to add to the existing activities a comprehensive awareness towards mitigation measures. The Institutional Review Board approves the current proposal.

The Review Board is composed of Wilson C. Medeiros, M.D; Celso Matias, M.D; Hebe Nóbrega, M.D.; Maria Zélia Fernandes; Drª Hebe Marinho, and Father Ausônio Tércio.

Sincerely

Profª Drª MARIA CRISTINA DAL PIAN NOBRE
International Office
Universidade Federal do Rio Grande do Norte

# Faculty of Education
# ETHICS APPROVAL FORM

To be completed by the applicant:

Title of Study:

An evaluation of the seismicity module used by Brazilian Primary (Early Years) teachers in Sao Paulo do Potengi

Name of Principal Investigator(s) (please print):

Name of Thesis/Dissertation Advisor or Course Instructor (if Principal Investigator is a student) (please print):

I/We, the undersigned, agree to abide by the University of Manitoba's ethical standards and guidelines for research involving human subjects, and agree to carry out the study named above as described in the Ethics Review Application.

Signature of Thesis/Dissertation Advisor or Course Instructor (if required)

Signature(s) of Principal Investigator(s)

To be completed by the Research and Ethics Committee:

This is to certify that the Faculty of Education Research and Ethics Committee has reviewed the proposed study named above and has concluded that it conforms with the University of Manitoba's ethical standards and guidelines for research involving human subjects.

Zana M. Lutfiyya
Name of Research and Ethics Committee Chairperson

Sept 13 2001
Date

Signature of Research and Ethics Committee Chairperson

## Appendix E

THE EARTHQUAKES EFFECTS

Topic - Safety

Goal: Prepare the students with some practical safety procedures to be used by them in case of earthquakes.

- Using the description of the damage caused by the earthquakes organize activities where the students will be able to observe the importance of implementing some practical safety procedures.

Sample Activity :

Imagine the occurrence of an earthquake in the classroom with the same intensity of the one that happened in the region (or you could work with other situations and adapt them to the classroom). Using the reports from the students, make the environment to look real, for example, move objects, draw with chalk, or tape cracks in the walls, and so on.

Through the discussion of the situation, find out the possible practical safety procedures that can be taken to protect people from getting hurt and to prevent further buildings from collapsing.

As we know earthquakes are not predictable, in the sense that we cannot determine the exact time when a quake is going to happen. Thus, it is very important that some safety measurements be adopted, for example, in the design of structures of bridges, buildings, dams, etc. With regards to other measures, which should be taken during and after an earthquake for our own safety as well as the safety of others, we can list:

- If you are inside of a car, stay there, because you are going to be more protected there.
- If you are inside of some kind of building, protect yourself from what could fall. Staying under a table or bed is a good choice. After the first tremors, get up fast and close off the water, electricity, and gas. Doing this you can avoid fires and the waste of water.
- During the first months after the earthquake, you should take some safety measures, because it is always possible that some other tremors could occur during this period. So, remove the heavy and dangerous objects from the shelves, as well as, the objects that are hanging from the walls and ceiling. Avoid being under the verandah, *marquises*, balcony, and leave buildings which present cracks originating from the first quake.

These activity can be completed with the design of a list of safety procedures which come up from the discussion and following a simulation where the students could apply the safety procedures discussed.

## Appendix F

Questões:

1. Qual era o comportamento das pessoas durante a ocorrencia dos terremotos?
2. Qual era a reação dos alunos com relação aos terremotos?
3. Qual a importância do Modulo de Sismicidade? ( Quais são seus pontos negativos e positivos?)
4. Voce encontrou algum tipo de dificuldade para trabalhar com o modulo?
5. Existe algum conceito central ou mais importante trabalhado no modulo?
6. O material mudou a sua concepção sobre terremoto?
7. Existem lugares que sejam mais seguros do que outros ? Onde? Quais são eles?
8. Vamos supor que você está em sala de aula e derrepente ocorre um terremoto. O que é que você faria? Qual seria a sua reação? E depois, como é que você, se tivesse chance, continuaria a aula?