CHAPTER TWO

LITERATURE REVIEW

This chapter reviews related literature on key aspects of the study. A search of related literature has shown there is a dearth of information on students' conceptions about earthquakes, particularly in southern Africa. The chapter first examines the theoretical concepts related to research in this field, with the focus on constructivist views of learning and socio-cultural factors influencing learning. Second, background information on earthquakes is provided to emphasise the current scientifically acceptable view about earthquakes. Third, an overview of the terms used to describe alternative conceptions in science is provided. Finally, the chapter presents a review of literature on people's ideas about earthquakes.

2.1 THE CONSTRUCTIVIST VIEW OF LEARNING

This study was conducted within the social constructivist framework, which offers a theoretical perspective about the interdependence of individuals' construction of knowledge and the social environment. This interdependence is reflected in Vygotsky's formulation of the general genetic law of cultural development, which states:

> *Any function in the child's cultural development appears twice, or on two planes. First it appears on the social plane, and then on the psychological plane. First it appears between people as an interpsychological category, and when within the child as an intrapsychological category* (Wertsch, 1985:60).

This view implies that children develop ideas about natural phenomena as a result of social and cultural influences.

Watts and Bentley define constructivism as:

> *a family of theories that share the assertion that human knowledge and experience entail the (pro)active participation of the individual* (Watts and Bentley, 1991:18).

The constructivist position holds that knowledge is not passively received, but is actively built up by the cognising subject (Von Glasersfeld, 1989; Driver *et al.*, 1994). Different proponents of constructivism emphasise different aspects about construction of knowledge. Radical constructivism, on the one hand, focuses on personal construction of knowledge. This perspective posits that the learner constructs his own knowledge which is idiosyncratic, that is, the meaning constructed is peculiar to the individual learner (Piaget, 1964; Von Glasersfeld, 1989). Jaworski (1997) has interpreted this view to mean that learners should perceive science as what they observe.

Some researchers have criticised the radical constructivist perspective, arguing that its individualistic emphasis appears to put a learner in a privately constructed experiential world of his or her own (Ernest, 1993; Matthews, 2000). The personal and idiosyncratic meanings constructed by a learner seem to ignore the influence of the social environment within which a learner constructs knowledge. This individual focus provokes the question "*whose reality is most real*?" (Matthews, 2000:498). Ernest (1993) refers to this unrealistic individual focus as romantic progressivism, and asserts that it considers anything the learner does as an expression of their individual creativity, and it naively assumes that the learner can discover much of conventional school knowledge on his own.

The social constructivist approach, on the other hand, emphasises that knowledge is acquired through interaction with others as well as by individual processes. This perspective ties in with the present research which is grounded on the viewpoint that the socio-cultural context of a learner has a significant role to play in the learner's construction of knowledge. This study examines how high school students in Lesotho acquired knowledge about earthquakes through interaction with others, as well as on an individual level. As Bruner (1985) has argued, there is no way in which a human being could master the world without the assistance of others. This view correlates with Jaworski's assertion that though learners construct scientific knowledge for themselves, "*it is unreasonable to expect that they will do it solely of their own accord*" (Jaworski, 1989:249). Driver *et al*. (1994) contend that learning science involves being initiated into the ideas and practices of the scientific community and making these ideas and practices meaningful at an individual level. This means that construction of scientific knowledge incorporates individual knowledge as well as knowledge constructed and agreed upon by the scientific community. Therefore, this knowledge is not privately held, but communal (Driver *et al*., 1994). This viewpoint shows the need for teachers' intervention in order to provide appropriate experiential evidence and to make the cultural tools and conventions of the science community available to students (Driver *et al*., 1994). Teachers should interact with the learners to ease the understanding of socially accepted knowledge. In this way, learners' knowledge will not be singly based on individual knowledge construction. Jaworski (1997) asserts that in a social environment, learners construct ideas new to them when individual knowledge is challenged through the use of language and social interactions. The contention that learners construct their own meanings implies that different individuals may construct alternative conceptions from the same information. This view explains why learners in this study may have different conceptions about earthquakes, in spite of having been taught the same content about earthquakes in school. This research aims at finding these different viewpoints.

The theory of constructivism is characterised by the recognition of and respect for learners' prior ideas (Ausubel, 1978; Ogborn, 1997; Jenkins, 2000; Martinez-Delgado, 2002). According to Ausubel (1978), learners' prior ideas impact on the learning of new scientific concepts. In his principle of meaningful learning, Ausubel states:

> *The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly* (Ausubel, 1978:iv).

Meaningful learning is therefore seen to occur when learners interact and relate new concepts to the mental models they already possess (Brook *et al*., 1989). This view correlates with Piaget's belief (1964) that the new ideas learnt at school should link with the child's existing mental schema. According to Hewson *et al*. (1998), valuing learners' ideas is good pedagogic practice, as it is the basis for conceptual change. They contend that discussing the range of ideas held by students during science lessons enables students to realise the variety of ideas harboured about the topic or concept being discussed. In this way students have the opportunity of choosing between different ideas, and the 'status' of some ideas is reduced, while the status of the idea that seems to be more intelligible, plausible, and fruitful is raised within the learner's conceptual ecology (Hewson *et al*., 1998).

When teachers recognise learners' prior knowledge during instruction, this enables learners to fit together the ideas from school science knowledge with their experiences, in an attempt to make sense of the world. This helps in bridging the gap between everyday experiences and scientific knowledge, should such a gap exist. The emphasis on the incorporation of teaching based on students' prior ideas is what distinguishes constructivism from teaching based on traditional practice, which does not value learners' prior knowledge. In traditional practice, learners were considered to have minds like blank slates with no prior ideas on the topic to be taught, and that they were ready to receive knowledge passively (Gilbert *et al*., 1982). Constructivism thus provides this research with a perspective from which to assess the students' ideas and perceptions. This perspective also helps to explain the existence of learners' misconceptions in science education, which may arise due to learners' failure to construct scientifically meaningful understandings, or their inability to link the new information with already existing schema. There is evidence that students have a tendency of maintaining their views despite classroom instruction (Simpson and Arnold, 1982; Driver, 1985; Cobern, 1994b cited by Aikenhead, 1996).

In recent years it has become clear through research that children develop beliefs or views about the natural world prior to formal instruction about scientific concepts (Driver *et al.*, 1994; Harlen and Osborne, 1985), and that in science classrooms, children's views may be incompatible with the scientific worldview. In order to promote meaningful learning in science classrooms, teachers should incorporate students' everyday experiences and understandings within formal science learning. Mayoh and Knutton (1997) assert that incorporating out of school experiences in science lessons can be a powerful tool in the hands of skilled teachers. This can also make a strong contribution to successful learning, by bridging the everyday experiences with the scientific domains. The teaching of earthquakes in schools is an important concept in the geography curriculum, and I support the idea proposed by learning theorists that students' experiences should be included in the teaching of earthquake concepts, so as to promote meaningful learning.

Some authors have cast a 'vote-of-no-confidence' in constructivism as a powerful model for school science education (Ogborn, 1997; Kragh, 1998; Jenkins, 2000). Jenkins (2000) questions the purpose of eliciting students' prior ideas, and argues that the pedagogical consequences of eliciting these ideas are far from clear. Researchers and educators are warned against uncritical espousal of constructivism, a model that appears to be merely a fashionable research paradigm (Jenkins, 2000). Kragh (1998) opposes attempts geared towards connecting science with human and social affairs, arguing that such efforts can be damaging and anti-scientific. Kragh's contempt for constructivism is seen in the claim that "*it is philosophically unsound, has weak empirical support, and is subversive not only to good science education but to honesty and critical thought in general*" (Kragh, 1998:242). Kragh claims that regarding science as a social construction denies the fact that the scientific worldview is grounded in nature and should be given higher priority than other worldviews. This argument ends with the suggestion that constructivism must be wholly rejected, though this does not imply a rejection of the socio-cultural perspective of science (Kragh, 1998).

I do not concur with Kragh's standpoint that the social constructivist approach should be discarded. Rather, I consider the constructivist perspective to have made a useful contribution to the multi-faceted challenges of education. As argued by Geelan (1997), a variety of complementary perspectives is vital to a deep understanding of educational problems. Thus, multiple perspectives add detail and richness to the picture (Brian, 1996; Geelan, 1997). In Brian's words:

> *…the world is not one dimensional, there is more than one way of viewing the world, many of which are valid in their own context, and many of which are compatible. In a two, three or multi-dimensional world perpendicular*

> *perspectives are in no way incompatible, indeed they give a fuller and richer description* (Brian, 1996:178).

Research conducted by Lee (1999) suggests that the role of prior knowledge is especially important for students from diverse social and cultural backgrounds because their cultural experiences and beliefs may differ from those of teachers and peers. In a study of American students' conceptions about hurricanes, Lee found that there were significant differences among the ideas of ethnic groups. For example, more African-American and Hispanic students expressed a belief in supernatural forces than the Caucasian students, who emphasised nature more strongly as the cause of hurricanes. Lee's finding suggests the importance of the influence of culture in shaping students' views about natural phenomena. The question of culture in science education is discussed in more detail below.

2.2 IMPACT OF CULTURE ON SCIENCE EDUCATION

The impact of culture on science education is discussed under four subheadings. First, the issue of school science as a foreign culture to Basotho students; second, the influence of the "subculture of science" (Aikenhead, 1996) on students' learning of science; third, the concept of cultural border crossing as proposed by Aikenhead (1996), and finally, debates on the issue of multiculturalism in science education.

2.2.1 School science as a foreign culture for Basotho students

According to Kannapell (2000), culture is the learned and shared behavioural patterns of a group of people with a shared language, identity and beliefs, and that language is a vehicle through which the soul of a particular culture is communicated to the world. Rollnick (2000) supports this idea by pointing out that culture is expressed in the form of language which is used to communicate and express norms, beliefs, values, and knowledge of a particular cultural group. Whorf (1972) contends that language and culture have grown up together, influencing each other.

In Lesotho, English is the medium of instruction in science lessons. However, it is a second language for almost all the learners in primary and high schools. This means that as English second language speakers, the learners are faced with a double challenge of learning English and its social practice, and science content which has its own discourse (Rollnick, 2000). Halliday and Martin (1993, cited by Rollnick, 2000) assert that even first language English speakers are alienated by scientific discourse, because it differs from the English of everyday usage. The difficulties experienced by high school students in Lesotho in understanding science concepts cannot therefore be overemphasised, since the difficulties of learning English and science content are compounded by the existence of Basotho cultural beliefs.

2.2.2 Influence of science as a subculture on the learning of school science

Aikenhead (2001) argues that science as a subject seems foreign to most students in school science, irrespective of whether they live in Western or non-Western communities. In most cases, school science culture is different from learners' home culture. The two cultures are not only different, but also conflict in some areas, a problem pointed out by Aikenhead and Jegede (1999), and Dzama and Osborne (1999). Learners in Lesotho are presented with a learning culture that is different from that of their home culture. An example of such a conflicting culture is illustrated by the explanation of cyclones. In school science, students learn that the coming together of warm and cold air masses causes cyclones, while in Basotho culture cyclones are said to occur when a 'water-snake' moves from its lake residence to another habitat. This example illustrates that often there is a gap between the culture of science and learners' traditional culture. Science students are expected to construct scientific knowledge meaningfully even though this knowledge may be in conflict with their indigenous beliefs. Learners' success in science is determined by how effectively students move between these cultures. Aikenhead and Jegede (1999), and Dzama and Osborne (1999) argue that cultural commitment hinders learners' ability to move between the culture of their family and the culture of school science, hence limiting their success in developing scientific ideas. This implies that students with high levels of beliefs in African cultural ideas are likely to perform poorly in science subjects (Dzama and Osborne, 1999).

The learner-centred teaching methodologies encouraged by progressive science educationists have little appeal to Basotho students. In their upbringing, Basotho children, like Chinese children as documented by Sutton and Tse (1997), are taught to respect the wisdom and knowledge of their elders. They are told not to question anything said by their elders. In school, this attitude is then transferred to respect for the teachers, because of their expertise and wisdom. Consequently, a teacher-centred approach would be more appropriate for teaching science education in some developing countries (Sutton and Tse, 1997), including Lesotho. Currently, the learning practices commonly advocated in science education produce a dichotomy in terms of the cultural upbringing of learners and the new Western culture being imposed upon them by progressive schools. This indicates that there is a need for culture-sensitive teaching strategies, as pointed out by Lubben *et al*. (1999). Geelan (1997:19) argues that "*culture is a central force in the development and organisation of student ideas*". Children's beliefs or views often emanate from their home culture. Therefore in order for learning to occur, the home culture of the learner must be explored and understood by teachers (Geelan, 1997).

2.2.3 Cultural border crossing in learning

The implication of the cultural clashes discussed above is that learners have to move between the culture of science and their everyday culture. Thus, for successful learning, there has to be "border crossing" between cultures as suggested by Aikenhead and Jegede (1999). Border crossing is a concept that attempts to explain how students move from their life-world culture to the subculture of school science. Students' transition between the subcultures of their peers and family and the subculture of school science is conceptualised as 'cultural border crossing' (Aikenhead, 1996). As students move from one subculture to the other, they subconsciously alter certain beliefs and values. Thus they negotiate the 'cultural border' between their lived experiences and the science classroom (Aikenhead, 1996). Students' success in science is determined by how effectively they move between these cultures.

Transition between cultures (school science and home culture) has been classified as smooth, manageable, hazardous or impossible (Aikenhead, 1996; Aikenhead and Jegede, 1999). Students with low levels of African beliefs experience smoother transitions because of the low degree of cultural difference between their life-world and that of school science. Aikenhead and Jegede (1999) contend that the more strongly family culture diverges from the culture of school science, the more hazardous the students' border crossing into science becomes, and it may be virtually impossible in some cases. The challenge for science teachers is to help students navigate the border crossing between these cultures. Thus teachers should act as "culture brokers" (Stanley and Brickhouse, 2001).

2.2.4 Multiculturalism in science education

There has been an ongoing debate in the past decades on the interaction between indigenous beliefs and school science. Several authors have shown contempt for the mono-cultural, Eurocentric worldview of science which has excluded other traditions of knowledge (Makhurane and Kahn, 1998; Volmink, 1998; Kyle, 1999; Odora Hoppers, 2001). These authors acknowledge that western science is invaluable, but point out that it should not undervalue other cultures. Volmink (1998) and Kyle (1999) propose a contextualised science education curriculum linking science education to learners' everyday experiences. These authors contend that valuing indigenous knowledge in science and technology could enable relevant, meaningful and contextualised science education which supports the goals of African societies. Odora Hoppers (2001) calls for the recognition of indigenous knowledge systems in order to develop a pluralistic and dynamic view of national heritage. She argues that the development of knowledge is a holistic journey, which encompasses the culture in which learning takes place.

The present school science curriculum is alienating to Basotho students in the sense that, as pointed out by Odora Hoppers (2001), science education curricula and examinations have a clear cultural bias toward European life styles and beliefs. The cultural bias is usually evident in examination questions in Lesotho. For example, a question in the 1999 Cambridge examination paper, which is the exit exam used in Lesotho, about the 'Titanic' created a calamitous situation in examination results. Students in Lesotho are not familiar with water transport as Lesotho is a landlocked country. Also, many students, especially those attending schools in the rural parts of the country, had not seen the movie by this name, which documents the tragic sinking of the Titanic. Thus 'Titanic' was a foreign concept to the students. Solano-Flores and Nelson-Barber (2001) contend that knowledge and experience are inseparable, and the need for contextualising relevant experiences in the curriculum and in assessment is clearly shown in this example.

The discussion in this section has focused on the notion that children develop ideas prior to formal instruction. These ideas may prevail even after instruction. Sometimes students' views may differ from the scientific view. The present study seeks to explore ideas about earthquakes held by Basotho students. Students in the sample are from an area where an earthquake was experienced a few years ago. Their views about earthquakes may resemble knowledge learned from geography lessons at school, or their views may be the result of a lived experience of this phenomenon, or from interaction with members of their community, and/or from the media. The views from these high school students will be analysed to check whether they are scientifically correct or not. In addition, these students' conceptions will be compared with those of others in different parts of the world. It is therefore necessary, first, to clarify the scientific explanations of earthquakes before providing a review of the findings of earlier research done on students' ideas about earthquakes, and second, to examine the terms used to describe alternative conceptions in science.

2.3 DESCRIPTION OF EARTHQUAKES

This section of the literature review considers the nature of earthquakes as explained in geography and geology textbooks, including those used in Lesotho high schools, to provide a background for comparison of the scientific views with alternative views. The mechanisms behind the causes of earthquakes will thus be discussed, together with the resultant impact of earthquakes. The discussion will highlight the relationship between earthquakes, volcanoes and plate tectonics, and will draw a distinction between these phenomena. It has been deemed vital to include this explanation of earthquakes, volcanoes and plate tectonics in an effort to show that these phenomena are closely related, indicating the likelihood that students may include all or some of these concepts in their responses. Furthermore, these explanations will be useful in the interpretation of students' responses in terms of being either scientifically correct or incorrect. This inclusion is also justified on the grounds of enabling a reader without this background knowledge to make better sense of the nature of the students' conceptions of earthquakes obtained in the study.

2.3.1 Definition of earthquakes

Generally an earthquake is defined as the shaking of the earth's crust (Bolt, 1978; Helliwell, 1982: Strahler and Strahler, 1987; Vilakati 1994), or the vibration of the ground (Leet, 1948; Tarbuck and Lutgens, 2003). It is also defined as the movement along faults or plate junctions, causing shock waves going through the crust and mantle (Gilson, 1976).

2.3.2 Causes of earthquakes

The current main theory explaining the occurrence of earthquakes is the theory of plate tectonics. This theory is based on the idea that all parts of the earth's outer shell are moving. The theory posits that the earth's outer shell consists of several rigid slabs or 'plates' which are fitted against each other and move relative to each other, on a layer of softer rock beneath them (Glen, 1975; Bolt, 1978; Strahler and Strahler, 1987; Stein and Wysession, 2003). At the edge of a plate, where there is contact with adjoining plates, large tectonic forces operate on the rocks, causing physical and chemical changes in them (Bolt, 1978). Earthquakes occur primarily at three zones of tectonic plate boundaries: first, at the spreading zone where plates move apart or diverge; second, where plates collide or converge, with the result that the edge of one plate subducts beneath the other; and third, at transform faults where plate motion is parallel to the boundary and plates slide past each other (Glen, 1975; Bolt, 1978; Stein and Wysession, 2003). Figure 2.1 below shows the distribution of the major plates on earth.

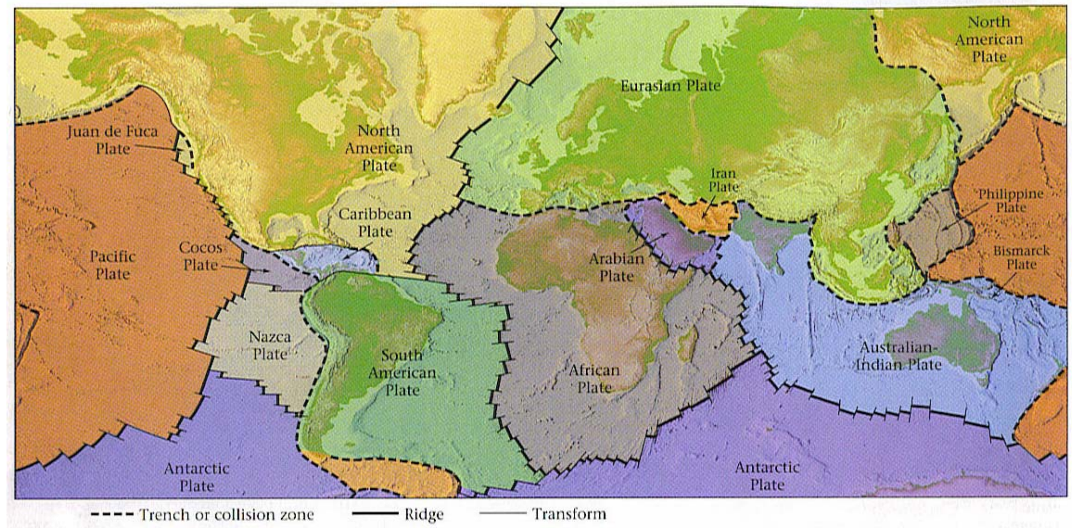

Figure 2.1: Map showing the major plates on earth (Source: Marshak, 2001:82).

Besides the movement of plates, earthquakes can also be felt during the movement of magma within a volcano as it pushes through the underground rocks. Thus volcanoes may cause earthquakes, which are sometimes referred to as "volcanic earthquakes" (Bolt, 1978; Eiby, 1980). As asserted by Bolt (1978), a fault rupture and massive landsliding may also produce seismic waves[4] resulting in an earthquake. Inevitably, faults and landslides are processes that are concomitant to earthquakes in the sense that they can **cause** earthquakes, but they can also **result from** violent ground shaking (Bolt, 1978; Vilakati, 1994; Stein and Wysession, 2003).

Though earthquakes are a natural phenomenon caused by forces within the earth's interior, certain human activities may also trigger their occurrence. These are commonly referred to as "man-induced" earthquakes (McCully, 1996). Mining is one such activity that may produce seismic waves, usually as a result of either a mine burst or collapse of a mine roof (Bolt, 1978). Reservoirs can induce earthquakes at seismic and aseismic areas (Bolt, 1978; McCully, 1996). Throughout the world there are many seismic events that have been correlated with large man-made reservoirs. Reservoir induced seismicity may occur immediately after impoundment of water or after several years (Seismology Research Centre, 1998).

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[4] Shock waves produced by a rapid release of elastic energy due to stress (Tarbuck & Lutgens, 2003).

Examples of reservoirs that induced seismic events in areas previously thought of as seismically inactive include Koyna in India (Bolt, 1978) and Katse in Lesotho (International Rivers Network, 1997). In both cases shaking became prevalent a few months after impoundment began.

According to the Seismology Research Centre (1998), large new reservoirs can trigger earthquakes due to the following two main factors: first, changes in stress because of the weight of water may cause landslides. The enormous volumes of water in large reservoirs results in isostatic[5] adjustment of rocks below the reservoir (Gilson, 1976), causing the earth's crust to rise or sink in response to the incumbent load of water. Second, the filling of a reservoir may result in increased ground water pore pressure (Bolt, 1978; Seismology Research Centre, 1998), which is a result of diffusion of reservoir water through permeable rocks under the reservoir. Bolt (1978) reports the results of an experiment in which water was alternately pumped in and out of wells, which showed a positive correlation between the quantity of fluid injected and earthquake activity. The Seismology Research Centre (1998:2) points out that "*fluid injection into wells in USA, Japan and elsewhere has triggered small earthquakes*". However, it should be borne in mind that pore pressure depends on permeability of rocks. Other human activities that may induce seismic events include blasting of rocks for constructional purposes and nuclear explosions.

2.3.3 Effects of earthquakes

Earthquakes are usually accompanied by several occurrences. The main effect of an earthquake is the shaking of the ground (Strahler and Strahler, 1987). In most cases earthquakes are accompanied by sound which is commonly referred to as "*earthquake sound*" (Leet, 1948:49). Bolt (1978) explains the occurrence of this sound by pointing out that seismic waves have a sound-like nature and therefore may be transmitted into the atmosphere as sound waves.

Usually earthquakes are accompanied by faults and landslides (Bolt, 1978; Eiby, 1980; Elders, 1989; Vilakati, 1994; Stein and Wysession, 2003). In some cases earthquakes result in liquefaction (Bolt, 1978; Strahler and Strahler, 1987; Stein and Wysession, 2003), which is a temporary change in state of soil and sand upon being shaken, from a solid to a liquid-like state that is not capable of supporting structures (Bolt, 1978; Tarbuck and Lutgens, 2003). The soil

[5] Isostasy refers to the state of equilibrium maintained by the earth's crust. If anything occurs to modify the existing state, a compensating change occurs to maintain a balance (Whitten and Brooks, 1972). When mass is added to or removed from the crust, the crust subsides or is uplifted (Tarbuck and Lutgens, 2003).

develops liquid properties, allowing some parts of the ground to subside (Strahler and Strahler, 1987). Another common effect of major earthquakes is the gushing out of ground water onto the surface (Leet, 1948; Bolt, 1978; Eiby, 1980) and the ejection of sand and mud (Elders, 1989). In some areas, glaciers and seawater may be driven to the land, the latter being a result of tsunamis[6] or giant waves in oceans produced during a major earthquake, owing to the sudden movement of the sea floor (Bolt, 1978; Eiby, 1980; Strahler and Strahler, 1987; Vilakati, 1994; Stein and Wysession, 2003).

When an earthquake occurs, especially in or near built-up areas, it may cause collapse and damage of infrastructure such as buildings, dam walls, bridges, underground pipes, etc (Helliwell, 1982; Strahler and Strahler, 1987; Vilakati, 1994; Stein and Wysession, 2003). Sometimes collapsing infrastructure results in the loss of life and damage of property. The degree of destruction of man-made structures depends largely on the nature of the buildings and their ability to withstand the shaking produced by seismic waves. Destruction of the natural environment and vegetation may also occur during an earthquake. An earthquake might lead to streams or rivers drying up, and ground breakage or cracking usually happens during an earthquake (Elders, 1989). Leet (1948) asserts that earthquakes may also be accompanied by a cloud of dust or fire outbreak which may be the result of electrical short circuits or lightning from thunderstorms.

Other effects of earthquakes are those associated with volcanic eruption. These will be discussed in the next section which pays more attention to the relationship between earthquakes, volcanoes and tectonic plates.

2.3.4 The relationship between earthquakes, volcanoes and plate tectonics

Earthquakes and volcanoes often accompany each other in those regions associated with plate boundaries (Bolt, 1978). Eiby (1980) points out that earthquakes and volcanoes are different outcomes of the same underlying geological processes. Both earthquakes and volcanoes occur at plate boundaries: earthquakes occur where the plates submerge, diverge or spread apart, while volcanoes are also generated at most plate boundaries where magma upwells between tectonic plate boundaries (Rowland, 2003). Figures 2.2 and 2.3 respectively, show the location of most earthquakes and the distribution of volcanoes. As pointed out by Eiby (1980), and as illustrated

[6] Large and often destructive sea waves caused by an earthquake (Moore, 1981; Funk and Wagnalis, 1982). Seismic sea waves were given the name *tsunami* by the Japanese, who have suffered a great deal from them. The term *tsunami* is now used worldwide (Tarbuck and Lutgens, 2003).

in these figures, there is a broad similarity between the world pattern of earthquake belts and that of active volcanoes. For a clear relationship between earthquake belts, volcanic regions and plate boundaries, the two maps (Figures 2.2 and 2.3) can be compared to the map showing the major plates (Figure 2.1).

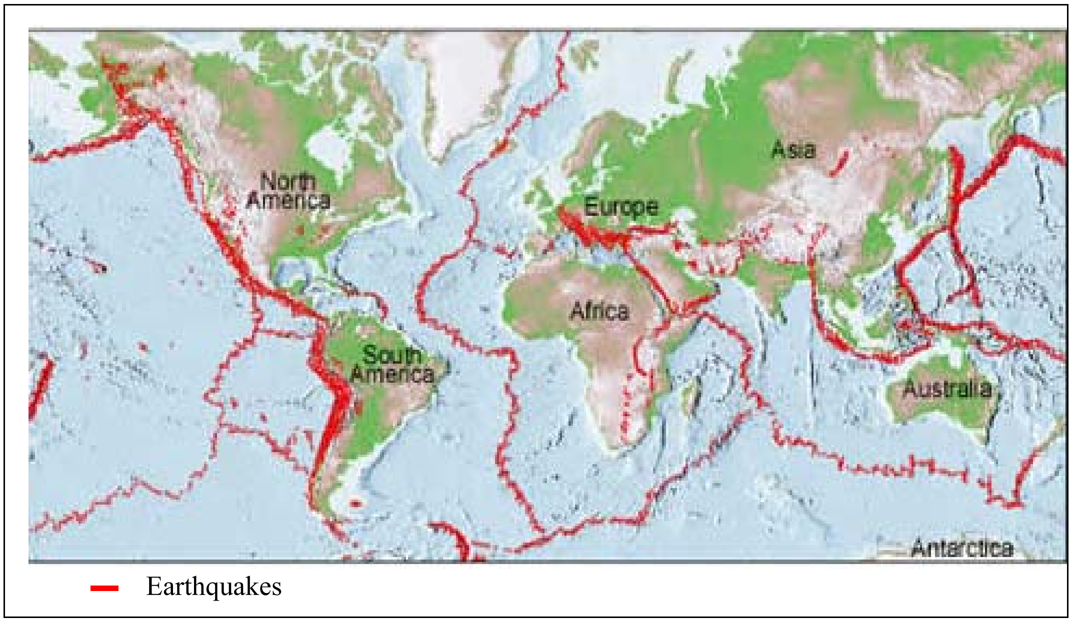

Figure 2.2: Map showing the location of most earthquakes (Source: Marshak, 2001:83).

Figure 2.3: Map showing the distribution of volcanoes worldwide (Source: Marshak, 2001:156).

Earthquakes and volcanoes occur together in two ways. First, earthquakes may cause volcanic activity due to ground shaking which may act as a triggering mechanism to the eruption of magma (Tilling *et al*., 1976). There are several examples of earthquake occurrences that were shortly followed by magma eruption or caldera[7] unrest. These include Kilauea volcano in Hawaii, Mauna Loa volcano, and Mount Pinatubo in the Philippines (Tilling *et al*., 1976; Macdonald *et al*., 1983). According to Newhall and Dzurisin (1988), throughout the world caldera unrest occurred at least 79 times in close association with earthquakes. The second way in which earthquakes and volcanoes occur together is when a violent eruption of magma results in seismic activity (Bolt, 1978; Eiby, 1980).

The above discussion of earthquakes has attempted to focus mainly on aspects that are relevant to the geography syllabus of Lesotho high schools, as it relates to this research. This description of earthquakes has been intended to highlight the scientifically acceptable views about earthquakes, which will be drawn upon while discussing the understanding that students in Lesotho have compared to students in other parts of the world.

2.4 TERMS USED TO DESCRIBE ALTERNATIVE CONCEPTIONS IN SCIENCE

The prevalence of alternative conceptions in science education has resulted in a plethora of terms used to describe learners' understanding of scientific concepts. The use of various terms by researchers may be explained by the constructivist perspective, that different researchers construct different meanings from similar experiences. Therefore their interpretation of research findings will differ (Gunstone, 1989). Examples of the terms used to denote conceptions that researchers consider as 'wrong' knowledge include 'misinterpretations' (Mahadeva, 1989), 'erroneous ideas', and 'misconceptions' (Abimbola, 1988; Gunstone, 1989; Mahadeva, 1989; Wandersee *et al*., 1994). Other terms used are those to describe unscientific beliefs held by societies. Mahadeva (1989) claims that these ideas are traditionally acquired from homes and other societal institutions. Examples of terms used here include 'myths' (Mahadeva, 1989), 'folk beliefs', 'superstitions', and 'intuitive beliefs' (Wandersee *et al*., 1994). Another group of terms are those that use non-judgemental and less condemnatory terms, such as 'preconceptions' (Fisher and Lipson, 1986), 'prescientific conceptions' and 'alternative conceptions' (Wandersee *et al*., 1994).

[7] A large central depression at the summit of a volcano, caused by collapse of the summit area (Tarbuck and Lutgens, 2003). Caldera unrest refers to significant changes in the level of thermal activity, such as geysers, hot springs and earthquakes, at a caldera (Bantley, 1994). This unrest may not lead to an eruption, but there is a possibility of violent explosive eruptions.

The terms chosen for use in the present study to describe students' ideas about earthquakes are 'students' conceptions' and 'alternative conceptions'. These terms are preferred for this study because they tend to have a neutral connotation and express tolerance for students' views. The focus of this research is to reveal a wide spectrum of students' understandings about earthquakes, not only 'misconceptions'. Some of the ideas expressed by students in this study may be scientifically correct, while others may be inconsistent with scientific knowledge, sometimes reflecting traditional beliefs.

2.5 STUDENTS' IDEAS ABOUT EARTHQUAKES, AS DOCUMENTED IN THE LITERATURE

Students' views about earthquakes seem to be an area that is largely unexplored (Ross and Shuell, 1993). A search of related literature located only a few published articles dealing with this topic, and no studies done in southern Africa were located. Thus there is currently limited literature on the topic. However, a review of the literature that is available helps the researcher in the following ways: first, according to Fraenkel and Wallen (1990), it helps to identify the results found by other researchers so that these can be used for comparison, and second, to investigate the problem with deeper insight and more complete knowledge (Leedy, 1997).

Table 2.1 provides a summary of studies done in different parts of the world, investigating ideas about earthquakes and related concepts including plate tectonics and volcanic activity. The details pertaining to place, sample, and methods used in the studies are provided to show that, generally, alternative conceptions about earthquakes and plate tectonics prevail worldwide and across age and educational levels.

Table 2.1: A summary of studies on people's ideas about earthquakes and other concepts related to tectonic plates

Author / Year	Place of study	Sample size	Sample details provided	Purpose / methods	Results
Turner, Nigg & Heller Paz (1986)	United States (California)	n = 1500	Adult residents of Los Angeles county	**Purpose:** To examine public response to earthquake prediction. To assess the extent to which people trust scientific as compared to non-scientific sources of earthquake forecast. **Methods:** A $3^1/_2$ years analysis of six population surveys were undertaken: ▪ Residents interviewed in their homes. ▪ Telephone interviews with smaller samples at intervals of five to six months after earthquake prediction. ▪ Telephone interviews conducted immediately after the occurrence of a moderate earthquake.	▪ 55.7% of the respondents expressed faith in scientific prediction of earthquakes but also believed in some non-scientific form of earthquake prediction. ▪ The majority of respondents took scientific announcements more seriously even though they considered these announcements to refer to less destructive earthquakes than prophetic and pseudo-scientific announcements. ▪ The majority of respondents expressed belief in "folk signs": 67.5% said they believe in unusual animal behaviour as an earthquake sign, 43.5% believed in earthquake weather, and 38.5% in premonition. ▪ About half of the sample (53.5%) claimed to understand something about tectonic plates. ▪ Whenever people had 'earthquakes' on their minds, they were thinking of damaging earthquakes.
Philips (1991)	United States (Delaware)	Not stated	K – 12 pupils, college students and adults	**Purpose:** To compile a list of commonly held misconceptions in earth science. **Methods:** Not stated	Results that relate to this study: ▪ Some adults had a misconception that "continents do not move". ▪ Some students believed that future earthquakes would not severely damage Chicago. ▪ Some college students had a misconception that "the earth is molten except for its crust".
Ross & Shuell (1993)	United States (New York & Utah)	n = 91 48 girls 43 boys	Kindergarten to sixth grade pupils from different schools ▪ 1st school - 35 pupils from grades K – 6	**Purpose:** To determine elementary pupils' conceptions about earthquakes. To ascertain whether there would be fewer misconceptions about earthquakes after experiencing one. **Methods:** Pupils were interviewed individually	▪ The experience of an earthquake did not guarantee scientific knowledge. ▪ Classroom instruction on the topic did not guarantee a reduction in misconceptions. ▪ The majority of students who lived geographically closer to volcanic area had the most confusion

			▪ 2nd school – 33 pupils from grades 4 – 6 ▪ 3rd school – 23 pupils from grades 4 – 6 ▪ Some of the pupils had experienced an earthquake ▪ Some pupils had received formal instruction on earthquakes	for approximately 15 minutes each.	between earthquakes and volcanoes
Bezzi & Happs (1994)	Northern Italy	n = 990	▪ Pupils from 37 secondary schools ▪ Pupils aged 14 - 16 years ▪ All pupils living in a non-volcanic but seismic region	**Purpose:** To discover pupils' ideas on the volcanism of the area in which they live. To discover the way pupils formed their opinions and how deeply rooted they were. **Method:** Questionnaires	▪ Pupils who lived in a seismic region related their experience of earthquake activity to expectations of volcanic activity ▪ Approximately 22% of the students had an incorrect notion that there is a likelihood of volcanic activity in the foreseeable future
Coleman & Soellner (1995)	United States (Missouri)	n = 40	▪ University students ▪ Adults (general public) in the university service area.	**Purpose:** To investigate whether students could apply their scientific knowledge to assess whether the prediction of an earthquake was scientifically based or not. **Method:** Pre – post questionnaire with fixed response and open-ended questions.	▪ Students were able to use their knowledge of scientific processes to assess the prediction of an earthquake as being either scientific or non-scientific. 69% of the students felt that the earthquake prediction had no scientific basis. ▪ Although students believed the prediction was not scientifically based, their personal feelings led them to believe that schools should be closed contrary to the belief that the earthquake prediction was not scientifically based.
Allain (1996)	France	n = 200	▪ 8 – 10 year-old pupils	**Purpose:** To assess children's ideas about the causes of seismic activity. To measure the impact and role of	▪ Children had ideas about continental drift and plate movement prior to receiving instruction on these concepts.

				earthquake-related pictures on children's knowledge construction. **Methods:** Tests.	▪ Many pupils described volcanoes as the cause of earthquakes. ▪ Some children described atmospheric processes such as the ozone layer and weather conditions as causes of earthquakes. ▪ Some children expressed the idea that the earth's rotation was a cause of earthquakes.
Barrow & Haskins (1996)	United States (Missouri)	n = 186	▪ University students enrolled in an introductory geology course.	**Purpose:** To determine students' knowledge of earthquakes before dealing with an introductory geology course. To determine the influence of an earthquake experience and that of the mass media on students' understanding about earthquakes. **Methods:** Open-ended questionnaire	▪ Generally students lacked knowledge about the relationship between earthquakes and volcanoes. ▪ Many students lacked a broad understanding about the theory of plate tectonics. The mass media provided more students with greater details about the cause and impact of earthquakes than the experience itself.
Gobert (2000)	United States (Massachusetts)	n = 47	▪ Fifth grade pupils ▪ Pupils aged 10 – 12 years.	**Purpose:** To identify mental models held by pupils about the inside of the earth. To identify pupils' models about the causal and dynamic processes involved in plate tectonics. **Methods:** Paper-and-pencil instrument administered to 40 pupils. Individual interviews (45 minutes – 1 hour) conducted with 7 pupils.	▪ Young students can construct rich mental models of complex causal and dynamic systems of plate tectonics. ▪ Students can use the models of tectonic plates to make inferences.
Tsai (2001)	Taiwan (Nantou & Taichung counties)	n = 60 32 girls 28 boys	▪ Fifth and sixth graders aged 11 – 12 years. ▪ Pupils were from 7 different elementary schools.	**Purpose:** To explore students' worldviews about the causality of earthquakes after experiencing one, and after being exposed to scientific views from the public media and their teachers. **Methods:** Students were interviewed individually in a total of four rounds: 2 weeks, 2 months, 5 months, and 8 months after the earthquake. Each interview session took approximately 2-5 minutes.	▪ Several students (12%) attributed the causes of earthquakes to supernatural forces. ▪ 25% of the students had a worldview which combined supernatural forces and myths. ▪ Students struggled to reconcile their indigenous worldviews and the scientific worldview. ▪ Students with the information sources of parents and public media had more "myths" and scientific/myths worldviews.

Previous research has shown that many students lack a broad understanding of the connection between earthquakes and volcanoes. Bezzi and Happs (1994) for example, found that secondary school students who lived in a seismic area believed that the occurrence of earthquakes was related to volcanic activity. Allain (1996) had a similar finding that children thought earthquakes are always caused by volcanoes. Coleman and Soellner (1995) observed that students in their study had sufficient accurate scientific knowledge to assess the value of the prediction of an earthquake. However, these students still thought that schools should be closed based on the prediction, even though they thought the prediction was not scientifically based. These students also lacked knowledge about the relationship between earthquakes and volcanoes. As stated, Ross and Shuell (1993) found that some of the students surveyed in their study could not distinguish between an earthquake and a volcano.

In their investigation, Barrow and Haskins (1996) found that college students lacked a broad understanding about the theory of plate tectonics. Gobert (2000) contends that students are likely to lack detailed understanding about earthquakes because plate tectonics, which plays a defining role in understanding earthquakes, is difficult to understand. Gobert argues that this is so due to various reasons: first, because the processes of plate tectonics are largely outside of our direct experience and therefore unobserved; second, because the scale size of these processes is difficult for children to conceptualise; and third, the time scale of geological processes surpasses our reference of a human lifetime, making it difficult for students to understand these processes. The concept of plate tectonics may also be difficult for students to learn owing to lack of understanding of the concept on teachers' part. In one of the Lesotho geography teachers' workshops I attended on the 11-13th January (2000) held at Lesotho Sun hotel in Maseru, many teachers raised a concern about teaching plate tectonics. There was a general feeling among the teachers that they had difficulty in teaching the topic, either due to lack of understanding of the topic on their part, and/or because its explanation was too shallow in geography textbooks. As a follow up to this concern, the Central Inspectorate in Maseru in collaboration with the National Curriculum Development Centre, held workshops to address this issue and other topics that were seen to be problematic for teachers. One of the workshops was held on the 09-11th January 2001 at the Lesotho Sun hotel in Maseru, while another took place on the 19th - 21st July 2004 at Maseru Day High school. In both workshops, the aim was to improve teachers' competence in the teaching of geography.

2.6 CONCLUSION

Research on people's ideas about earthquakes has shown that children's views about earthquakes may not become scientifically accurate as they mature. The theory of constructivism is seen to be useful in explaining why some learners may continue to have alternative conceptions about earthquakes in spite of having received formal instruction on the topic. It is on this premise that social constructivism is the theory guiding this study, as the theory advocates individual knowledge construction and respect for learners' prior ideas originating from their interaction with society.

In order to elicit the students' ideas, a variety of methods were employed. These methods are discussed in the next chapter.