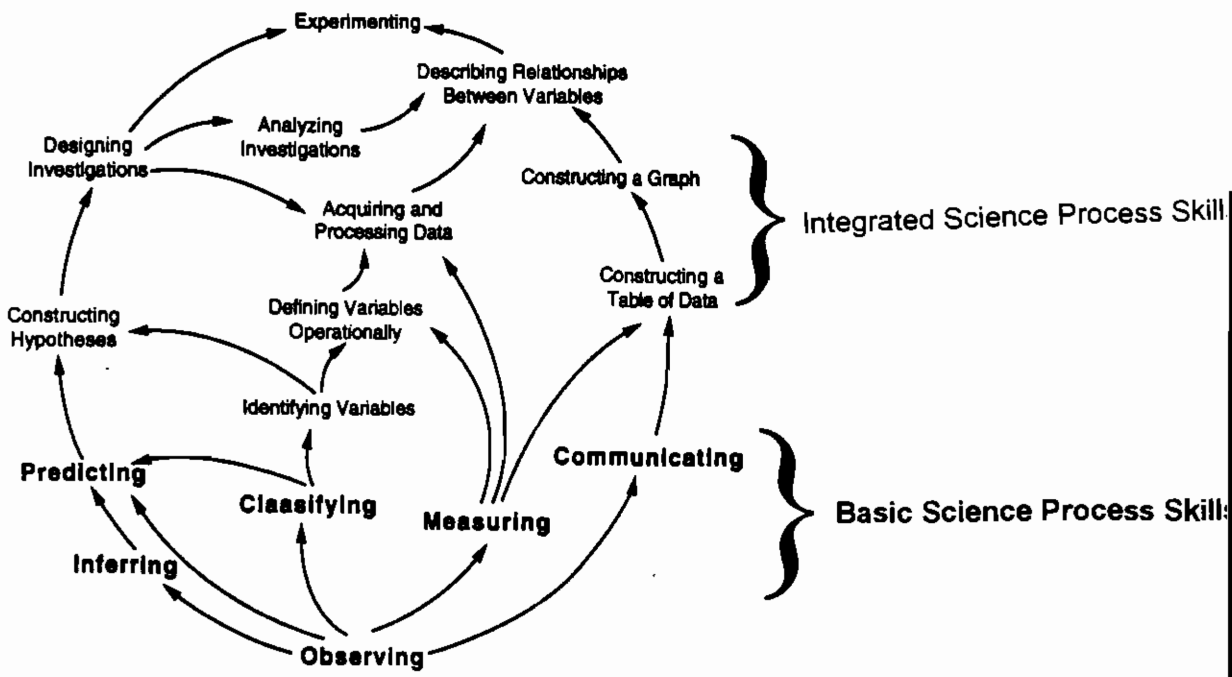
4.4 BASIC SCIENCE PROCESS SKILLS AND THE TEACHING OF GEOGRAPHY

Science process skills are arranged in a hierarchical order. Figure 4.1 depicts a hierarchy of science process skills.

Figure 4.1 A Hierarchy of Science Process Skills



(Rezba et al. 1995: 117)

In Figure 4.1, the foundation of all the skills is the observing skill. As the diagram indicates, the development of one skill in the hierarchy depends on the formation of other skills. These skills are classified as either basic science process skills or integrated science process skills.

It is possible to apply these skills to the teaching of geography (cf. 2.7). Friedl (1991: 137-216) has designed geographical experiments which geography teachers should demonstrate in their classrooms. This is likely to encourage geography learners to apply science process skills in their investigations. The learning of basic science process skills may empower learners to be active when they do geography. The basic science process skills that can be applied to the teaching of geography are observing, measuring, inferring, classifying, predicting and communicating.

4.4.1 Observing as a Process Skill Applied to the Teaching of Geography

Zeitler and Barufaldi (1988: 94) assert that observing is a basic skill of scientific inquiry (cf. 2.5.1.1 and 4.6.1). People observe through all their senses, namely, sight, touch, smell, taste and hearing. Sometimes a source of air pollution may not be visible, but we can smell it. People observe in order to obtain information about the world (Trowbridge and Bybee 1990: 49) or to identify features or changes in phenomena and to interpret those changes (Zeitler and Barufaldi 1988: 94). For instance, learners may observe that temperature gradually rises while entering the city centre from a surrounding rural area and they will realize that the city is a 'heat island'. In this example, changes in temperature are identified through feelings.

Friedl's (1991: 143) experiment for recording 'dew point temperature' on different days shows the use of sight in *observation*. The teacher may request learners to *observe* and record dew point temperature on different days. In this activity, the teacher places a few ice cubes into a jug of water. Learners are asked to insert a thermometer into the water and to carefully observe the temperature at which dew is first noticed on the outside of the jug. This activity is repeated several times on different days. Learners are expected to answer the following question every day of this experiment. *At what temperature does dew form on the outside of the glass?* Learners are likely to discover that the dew point is not at the same temperature every day.

As Van Aswegen et al. (1993:15) have observed, the examples of *observation* discussed in the previous paragraphs indicate that there are two forms of observation, namely, natural observation and experimental observation. The observation of changes in temperature while travelling from a surrounding rural area to the city's centre is a natural observation. The measuring of dew point temperature in the beaker of ice is an experimental observation. Van Aswegen et al. (1993:15) also maintain that the ability of learners is likely to improve in experimental observations if teachers and learners adhere to the following principles:

- *accuracy - the phenomenon should be accurate to make accurate observations.*
- *relevancy - learners should be prepared to make relevant geographical data.*
- *realism - learners should be provided with opportunities to observe geographical reality, i.e. they should observe the actual geographical phenomena.*
- *comprehensibility - the experiment, procedure, demonstration should be brought to the developmental level of the learners. It is more likely for learners not to comprehend observations that are beyond their level.*

Studies (Hanson 1958 cited by Miller and Driver 1987: 42; Friedl 1991: 143; Van Aswegen et al. 1993:15 and Zeitler and Barufaldi 1988: 94) indicate that observation is theory-laden. What individuals observe depends on proven theories. Theory guides observation, and without it one is incapable of deriving any useful knowledge. Millar and Driver (1987: 42) aptly put it, "*a theory provides guidance on what we expect to see in certain situations, on which feature of the event being observed, we should focus attention. Without a theory to guide, all manners of distracting and irrelevant data would necessarily be amassed*". The examples which were discussed above clearly support this line of argument. Observation is theory dependent. It is important to note that *experimental observations* need some sort of *measuring* in order to make accurate *observations*.

4.4.2 Measuring as a Process Skill Applied to the Teaching of Geography

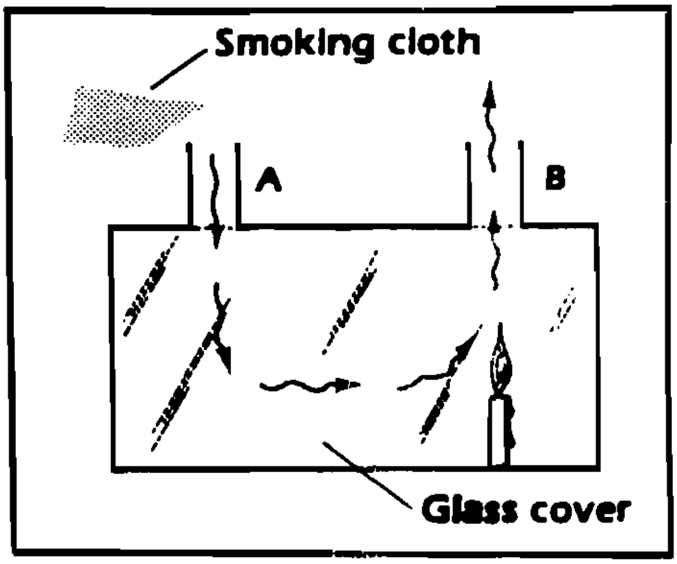
Van Aswegen et al. (1993: 16) contend that scientists are able to convey their observations in more precise terms through measuring (cf. 2.5.1.4 and 4.6.2). As indicated in Carin and Sund (1989: 69) and Mhlongo (1996: 100) measuring is explained as a skill for quantitative observations, comparing and classifying objects and for communicating effectively with others. Zeitler and Barufaldi (1988: 97-98) maintain that measuring quantifies through numbers. Objects or events are quantified with standard or non-standard units. For instance, to apply the standard unit of measuring, the teacher may ask learners to use a thermometer to measure temperature readings every day. The teacher may also apply the use of a non-standard unit of measuring by requesting a learner to touch a beaker full of water and then report to him/her if the beaker is warm, hot or cold.

Sauvain (1989: 26) suggests that measuring, depends on the topic, the type of hypothesis to be tested, the measuring time at one's disposal and the measuring instruments. After the measuring process, learners may be forced to explain or give meaning to what they have observed. This act of making sense of observation is an inference (Rezba et al. 1995: 77).

4.4.3 Inferring as a Process Skill Applied to the Teaching of Geography

Inferring (cf. 2.5.1.6 and 4.6.3) is the creation of explanations or drawing conclusions based on *observations* and a system of *classification* ((Trowbridge and Bybee 1990: 49). Learners may be requested to distinguish which statements are observation based and which ones are inferences. Friedl's (1991: 138) curious currents experiment (Figure 4.2) can be useful in the explanation of these processes.

Figure 4.2 Curious Currents



(Friedl 1991: 138)

Suppose, for instance, the teacher puts a convection box with two chimneys (i.e. chimneys A and B) and a sliding glass for viewing. Then the teacher lights a candle in the box below chimney B and closes the glass cover. The teacher holds a smoking piece of cloth over the top of chimney A. The teacher then holds the same piece of cloth above chimney B. Learners are likely to *observe* the smoke going down in chimney A, and at chimney B the smoke will go up. As such, learners are likely to *infer* that warm air rises and cold air descends.

After this demonstration, the teacher may write the following statements based on the information derived from the experiment and request learners to indicate if the statements are observation or inference:

The smoke goes down chimney A and goes up chimney B. (observation)

Warm air rises and cold air descends. (inference)

In this activity learners *classify* statements as either *observation* or *inference*. This example shows that the skill of *observing* is also linked to the skill of *classifying*.

4.4.4 Classifying as a Process Skill Applied to the Teaching of Geography

Classification roots can be traced back to the sensori-motor schemes (Piaget and Inhelder 1969: 102). Classification implies a relation of resemblance between members of the same class, and one of dissimilarity between members of different classes (Inhelder and Piaget 1958: 5). The classifying skill was explained as a process skill that involves the arrangement or ordering of objects or events into different classes or groups (cf. 2.5.1.2 and 4.6.4). Each classified group may have objects or events which have common features. Classification is used for convenience and to further understanding. Geographers frequently utilise classifications (Waugh 1990: 151) while studying types of climate, soil and vegetation, forms and hierarchy of settlement, and types of landform. Geographical phenomena are classified according to their characteristics, properties or criteria.

Learners should be made aware that in principle, every geographical phenomenon they observe, is slightly different from the same type of phenomenon they have encountered. This is because of the variable character of the earth surface. For instances, the mountains or rivers which one passes from Johannesburg to Cape Town are not the same. They differ as they are located at different places with different climatic conditions.

Learners may also observe familiar geographical phenomena acting in unfamiliar ways. For example, learners' previous observation may be that air temperature usually decreases with an increase in altitude, but there are certain circumstances when air temperature increases with altitude. The process whereby warm air overlies cold air is classified as temperature inversion.

Millar (1989: 53) argues that all people possess the ability to classify. We classify unconsciously and routinely. People have the capacity to classify unproblematically and to notice similarities and differences. Kuhn (1977) cited by Millar (1989: 53) that all learning depends on learner capability to classify. For example, when applying the classifying skill to the teaching of geomorphology, the teacher may list the following geographical phenomena and request learners to *classify* them. These are:

arch, braided river, corrie, delta, esker, hanging valley, knickpoint, moraine, raised beach, rapids, spit, and wave-cut platform.

This example shows the syntactical structure of geography (cf. 3.3.2) and learners have to perform a classification task as a competency they should be able to demonstrate. Hence, the outcome of this activity is that learners should be able to *classify* the features formed as a result of *erosion* or *deposition*. They should also be able to *classify* the features according to whether *they were formed under a previous climate* or whether *they are still being formed today*. Another outcome of this activity is that learners should be able to divide the phenomena into *coastal*, *glacial*, and *fluvial* landforms.

The teacher may ask learners if they can think of at least three different ways in which the listed geographical phenomena may be categorised. In order to classify the phenomena, the learners may make use of some of the possibilities listed below:

- the classification may be based upon whether the phenomena result from *erosion* or *deposition*;
- the phenomena may be reclassified into those formed under a *previous climate* (relict features) and those *still being formed today*, and
- the phenomena may also be divided into *coastal; glacial; and fluvial landforms*.

This example indicates the importance of knowledge to the development of science process skills and outcomes. For instance, for learners to perform this classification task correctly, they should be able to distinguish between erosion and deposition. Hence, they will be able to list features which are formed through erosion and those which are formed through deposition. This may not be possible if learners do not know what erosion and deposition are.

Furthermore, the basis for 'correct' or 'best' classification, is the use of criteria. Geography teachers may also develop the skill of classifying in the learners by articulating the criteria on which the classification is based. For example, the teacher may ask learners to classify the following economic activities for an urban settlement such as Welkom:

> *mining, farming, teaching and training, banking, manufacture of jewellery from gold, medical services, wool processing, buying and selling.*

The teacher asks learners to classify these activities according to whether they are *primary, secondary or tertiary* activities. In order to do this, learners should consider the characteristics of each type of activity. Hence knowledge of these characteristics is essential for learners to perform the task. For example, one characteristic of a primary activity is that it extracts raw materials (natural resources) from the environment. The extracted raw materials are not changed or processed into new products. A secondary activity characteristic is that a raw material is processed and changed into another product. Tertiary activities provide services to both primary and secondary industries. Without this information, some learners may not be able to attain the outcome of the lesson.

Millar (1989: 53-54); Millar and Driver (1987: 43-44) and Waugh (1990: 151) point out that when determining the basis for any classification, care must be taken to ensure that:

- *learners are capable of using a particular classification system;*
- *learners know the purpose of classification and are able to choose relevant criteria for classification;*
- *only meaningful data and measures are used;*
- *within each group or category, there should be the maximum number of similarities;*
- *between each group, there should be the maximum number of differences;*
- *there should be no exceptions, i.e. all the features should fit into one group or another; and*
- *there should be no duplication, i.e. each feature should fit into one category only.*

Carin and Sand (1989: 31) believe that classification abilities in children develop during the concrete-operational stage of development. Miller and Driver (1989: 43) maintain that classifying skill lies at the root of all cognition. Children who have developed classifying skills are capable of ordering and locating information in the mind which implies that children are likely to determine the properties, structure and function of different geographical phenomena. It can be safely concluded that once children are able to code geographical phenomena mentally, they are able to interact with their environment in a better way. Giving order to the environment is also likely to enable learners to recognize geographical patterns and to *predict* from these patterns what future *observations* might be.

4.4.5 Predicting as a Process Skill Applied to the Teaching of Geography

Zeitler and Barufaldi (1988: 101) maintain that prediction is based on background experiences (cf. 2.5.1.5 and 4.6.5). For instance, people may predict that an approaching tropical cyclone may cause damage to property and infrastructure because the cyclone is always accompanied by strong winds, heavy showers and flood waves along the coast. As such, they may take precautions that may minimize damage to property and lives. Prediction entails identifying the possibility rather than the assurance of the event.

Van Aswegen et al. (1993: 16) recommend that teachers should develop the skill of prediction in learners by asking questions such as "*What will happen if...*" (cf 4.3.3.2 and cf 4.3.4). This type of questioning stimulates and encourages learners to think about their *observations* and *experiments*. For instance, the teacher may ask learners to consider the following question: "*What will happen if moisture-laden warm air ascends a mountain*"? Learners are likely to *predict* that air will be cooled, condensation will take place, cloud formation will occur and that it may rain. This explanation is likely to assist learners to form a mental picture for the formation of orographic (relief) rainfall. The process by which the teacher asks learners to substantiate their answers is reflective teaching. The teacher qualifies the learners' answers by asking: *Why do you say that?* Hence learners may *communicate* their reasons to the teacher.

4.4.6 Communicating as a Process Skill Applied to the Teaching of Geography

Communicating is a skill which is much more complex (cf. 2.5.1.3 and 4.6.6). For instance, the South African Qualification Authority (SAQA) has accepted a critical outcome in which learners should be able to *communicate effectively using visual, mathematical and/or language skills in the modes of oral and/or written presentation.*

In support of this complexity, Zeitler and Barufaldi (1988: 100) claim that people need good understanding of scientific terminology to communicate effectively. If learners understand the meaning of terms, used in context, they are likely to explain interaction between objects or the results of actions. Learners could feel comfortable using the skill of *operational definitions*.

Sometimes, geographers communicate their ideas or findings through graphs. A Graph communicates a relationship between two variables or conditions (cf. 2.5.2.3). Van Aswegen et al. (1993: 16) state that learners should be given opportunities to think and to communicate their thoughts into spoken and written words, diagrams, drawings, graphs, maps, pictures and mathematical equations. The role of topographical maps in the development of some science process skills in learners is explained in section 4.6 of this chapter.

The skills reviewed above form the foundation for the application of integrated science process. These skills are known as integrated science process because they are used as a unit in *experimenting* (Rezba et al. 1995: vii).

4.5 INTEGRATED SCIENCE PROCESS SKILLS AND THE TEACHING OF GEOGRAPHY

This section attempts to highlight how teachers could introduce integrated science process skills in their teaching. Rezba et al. (1995: 117) suggest that learning these skills qualifies learners to answer many of their own questions which implies that learners may be able to interpret geographical phenomena they observe and to design geographical experiments to test their ideas.

Integrated science process skills which geography teachers should apply to the teaching of geography are - Defining variables operationally, hypothesizing, manipulating and controlling of variables, interpreting data and experimenting (cf. 2.5.2). Other science process skills such as constructing a table of data, plotting a graph, acquiring and processing data, designing investigation and analysing investigations are likely to be developed when the skills mentioned above are developed and promoted in geography lessons. The following is a discussion on the integrated science process skills that can be applied to the teaching of geography.

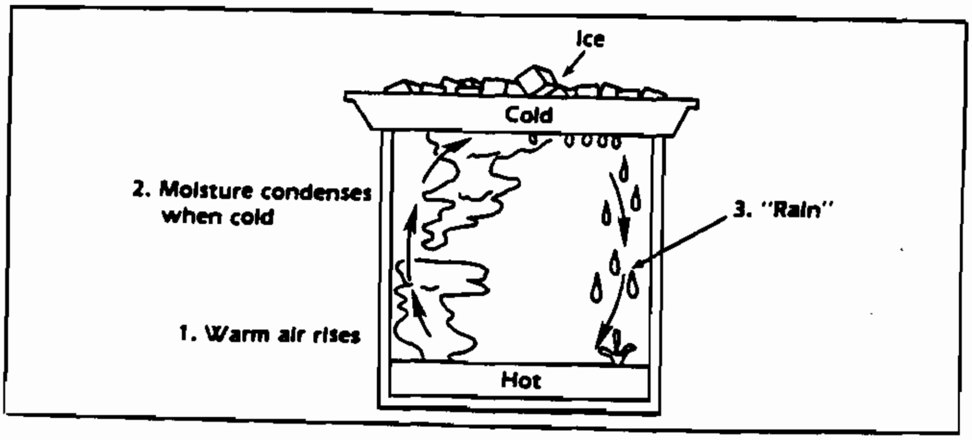
4.5.1 Defining Variables Operationally as a Process Skill Applied to the Teaching of Geography

According to Zeitler and Barufaldi (1988: 100) "*an operational definition is one designed by the investigator to clarify his/her meaning of terms, actions, conditions, or results within the scope of an investigation*". Operational definitions can be illustrated or verbalized (cf. 2.5.2.8). Aswegen et al. (1993: 17) maintain that learners should be able to differentiate between definitions that are operational and those that are not.

The development of this process skill could assist learners to communicate scientifically using terms that have definite operational meanings. Learners may also identify and explain what they regard as being the necessary condition for an experiment to be repeated successfully. The development of this skill also equips learners with the ability to construct operational definitions in problems that are new to them.

The skill of constructing operational definitions can also be developed through experiments. For instance, Friedl's (1991: 144) water cycle experiment allows learners to make operational definitions of evaporation, dew point temperature, humidity, rain, condensation, cloud, wind and the water cycle. Learners then, should also be capable of forming a theory on what causes rain. Figure 4.3 on the next page clearly indicates the major parts of the water cycle.

Figure 4.3 The water Cycle



(Friedl 1991: 144)

In the above experiment, the teacher sets up a small 'water cycle' in a jar. (S)he fills a large, wide-mouthed heat resistant glass, or plastic jar with 1 or 2 centimetres of hot water. (S)he covers the top of the jar with a metal pie plate filled with crushed ice. From time to time a small amount of smoke inside the container is added. When this is being done, learners should be able to identify and observe miniature forms of clouds, air movement, and rain. They should also be able to compare the conditions inside the jar with the conditions in the atmosphere. Learners' observation of this experiment may enable them to *define operationally* evaporation, dew point temperature, humidity, rain, condensation, cloud, wind and the water cycle as shown in Table 4.3. The table is as follows:

TABLE 4.3 Operational Definitions

TERM	DEFINITION
Evaporation	*Evaporation is the process whereby water changes from a liquid to water vapour and rises into the air.*
Wind	*Wind is moving air.*
Dew point temperature	*Dew point temperature is the point at which the rising warm air is saturated.*
Humidity	*Humidity is the amount of moisture in the atmosphere.*
Condensation in the atmosphere	*condensation is the process whereby rising warm moisture, cools and condenses to form clouds.*
Clouds	*Clouds are forms of condensation resulting from the rising and cooling of air.*
Rain	*Rain is precipitation in the form of water droplets that fall to the earth from clouds.*
The water cycle	*The water cycle is the process whereby water evaporates from the oceans and is transported by wind, in the form of water vapour and clouds, to the land, where it falls again as rain.*

Examples in Table 4.3 imply that the process of constructing operational definitions is a demonstrable task. The outcome of this task is that learners should be able to *observe* the experiment and give the meanings of scientific terminology. Furthermore, this experiment may also influence learners to *hypothesize* on what causes rain, hence learners may be able to form a theory on what causes rain. Learners are engaged in an integrated science process of *constructing hypotheses* on what causes rain and the hypotheses provides guidance on what data to collect to answer the question, *What causes rainfall*? This example also reveals that for an operational definition to be constructed, the teacher and learners should design an investigation and analyse it. Learners may also hypothesise the definitions of phenomena until they arrive at the best definition for those specific phenomena.

4.5.2 Hypothesizing as a Process Skill Applied to the Teaching of Geography

Hypothesizing is the activity of making an 'imaginative leap' beyond the data to try to account for observed features (Millar 1989: 56). A hypothesis is subject to empirical testing, validation, and possible rejection (Trowbridge and Bybee 1990: 49). It is a supposition stated in the form of a probable solution (Swanevelder et al. 1987: 7). Subsequently, a hypothesis is a tentative explanation or theorem of what the scientist thinks the outcome of his/her research will be (Van Aswegen et al. 1993: 17). It may also be a statement of the relationship that exists between two variables (Rezba et al. 1995: 219 and Zeitler and Barufaldi 1988: 100). Investigators who formulate hypotheses use their background knowledge, experience and information from other investigations (cf. 1.3.1 and 2.5.2.7).

Mhlongo (1996: 166) suggests that the hypothesizing skill may be developed from practical work rather than from teacher questions. Swanevelder et al. (1987: 41) maintain that geographers need scientific answers to a diverse of related problems. They require answers to:

- ☐ *relationships between physical phenomena;*

  For example, between distance from the sea and temperature, air pressure and wind, the amount of rainfall and percolation of water into the soil and so forth.

- ☐ *relationships between human phenomena;*

  For example, between distance from the markets and the pattern of production in crop farming, mechanisation and number of farm workers, agricultural raw material, transport costs, markets, and so forth.

- ☐ *relationship between physical phenomena and human phenomena,*

  For example, between water and type of settlement, steepness of slope and the location of a village, drought and depopulation *of a rural area; and so forth*

Learners should be capable of giving answers to the questions asked about these relations. Van Aswegen et al. (1993: 17) summarise the functions of the hypothesis as follows:

- *it serves to explain the relationship among variables;*
- *it brings order to an experiment by determining what is being tested and what is expected as a result; and*
- *it is of fundamental importance in giving direction to the research programme.*

The involvement of learners in hypothesis-testing activities is likely to empower them to derive useful and practical information from an hypothesis. It may also stimulate learners' interest in finding relationships between existing variables.

In the water cycle experiment (Figure 4.3), learners are likely to hypothesize that the water cycle is a source of rain. Furthermore, they may form a theory that for rain to occur, water should evaporate from water sources, then water vapour should rise, condensation should take place, cloud formation should occur, and precipitation in the form of water droplets should fall to the earth from clouds.

This process could contribute to the development of a critical outcome in which learners should be able to *collect, analyse, organise and critically evaluate information*. This is because learners need to *conduct and analyse investigations* and do research by means of experiments in order to test their hypotheses on what causes rain.

Data analysis depends on the complexicity of the collected data. Simple data does not require complex analysis whilst a complex data may require quantitative science process skills such as tables of data (cf. 2.5.2.2) and graphs (cf. 2.5.2.3). Learners analyse the collected data with the guidance of the teacher. Learners use the hypotheses listed as investigative guides. It is important for learners to be objective while analysing the collected data. They should emotionally detach themselves from the collected information.

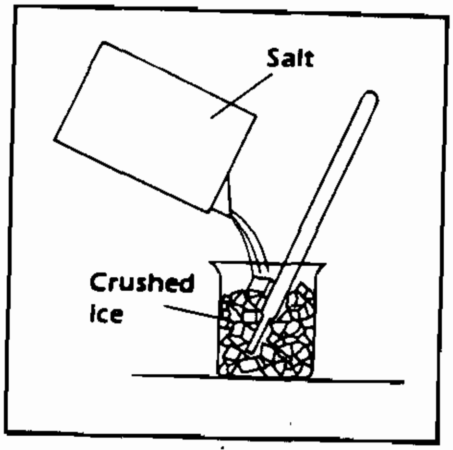
Another important point is that there is no hypothesis which should be viewed as correct or incorrect because all hypotheses are likely to lead to fruitful investigations. A hypothesis that is not supported by the collected data is rejected but it is not wrong. The investigator is supposed to redefine the problem, formulate new hypotheses and collect new data that will support the new hypotheses (cf. Figure 2.7).

4.5.3 Manipulating and Controlling of Variables as a Process Skill Applied to the Teaching of Geography

Zeitler and Barufaldi (1988: 99) are of the opinion that manipulating and controlling of variables begins when the investigator selects a variable to be changed or observed (cf. 2.5.2.1 and 2.5.2.4). They recommend that one variable should be manipulated at a time. If more than one variable is manipulated, it may not be easy for the investigator to determine the variable that has produced the result. The investigator may also not be able to determine if a combination of variables has produced the result.

For instance, Figure 4.4 on the next page indicates Friedl's (1991: 33) *Melt Ice ... Below Its Freezing Point* experiment. In this experiment, learners observe how the manipulation and controlling of variables affect temperature. The variables in this experiment are crushed ice and salt.

Figure 4.4 When Salt is Poured on Crushed Ice, What Happens to the Temperature?



(Friedl1991: 33)

In Figure 4.4 experiment, the teacher fills a beaker with about one-third of crushed ice. (S)he pours 4 to 8 tablespoonfuls of salt onto the crushed ice. Then, another one-third beaker of crushed ice is added. The teacher prepares the ice-salt mixture before the teaching period so that learners are not aware that salt was used.

The teacher shows the beaker of the ice-salt mixture to the learners. (S)he points out that liquid is collecting at the bottom of the beaker. Then, the teacher asks the learners to indicate the temperature at which ice melts. Most learners are likely to answer that it melts at 0 degrees Celsius. The teacher requests learners to register the temperature of the melted liquid with a thermometer. Learners are likely to find that the temperature is well below freezing point. The teacher then asks learners the question - *"How it is possible for ice to melt below freezing point?"* (cf. 4.5.5).

As already mentioned, there are three general categories of a variable, namely, independent (manipulated) variable, dependent (responding) variable and controlled (fixed) variable (cf.

2.5.2.1). These variables can be described as follows:

- Independent (manipulated) variable

This variable is the treatment that is expected to produce an outcome. It may be deliberateiy changed, since it is under the control of the investigator. It does not depend on the dependent variable, that it is why it is known as the independent variable. In the experiment discussed above, salt is the independent variable as it is the treatment that is expected to produce an outcome. The outcome here is that the crushed ice melts but the temperature remains very cold. As such, learners are expected to find the reason for the cold.

- Dependent (responding) variable

The dependent variable depends on the treatment it receives and it changes in response to the dependent variable. It is the condition to be measured, since it represents the outcome (effect) in response to the treatment (cause). In the experiment discussed above, temperature is the dependent variable because it depends on the added salt. It is important to note that the temperature of the melting ice remains very cold (effect) as a result of the added salt (cause).

- Controlled (fixed) variables

These are conditions that may affect the results of an investigation. However, they do not, as they are deliberately held constant. In the experiment, fixed variables are the beaker and the thermometer as they are not changed and remain constant.

4.5.4 Acquiring and Processing Data as a Process Skill Applied to the Teaching of Geography

A problem is identified after the teacher has recognized a cause and effect or correlational relationship to be investigated. The teacher plans in advance a question or problem that relates to the relationship. For example, on the question, "What *causes soil erosion?"* The class will start discussing the causes such as moving air, moving water, moving ice, overgrazing and so on. The teacher could also spontaneously introduce more facts about the cause of soil erosion.

The teacher also plans the data collection procedure beforehand because this procedure should enable learners to answer the question or solve the problem. Learners may select their data gathering instruments which could be literature sources, questionnaires and interviews and actual observation of soil erosion (fieldwork).

When one looks at the data gathering instruments named above, one can deduce that an inquiry lesson is not a single period activity. The teacher must take the available time into consideration when planning an inquiry lesson. To alleviate the problem of time, the teacher should integrate investigation of the question with other activities. For example, the teacher may assign the problem as a research project. The learners thus can be asked to record their investigations and submit an assignment on the factors that cause soil erosion.

The data sources learners' use to gather information can be either primary or secondary. In primary data sources, learners observe original data such as the process of soil erosion and interview people such as farmers and conservationists. In secondary data sources, learners consult sources such as literature and other reference books like encyclopaedias. The information contained in these sources has been analysed and interpreted by other researchers. This is second hand material which has perceptions and potential bias of others. Consequently, learners may be encouraged to use primary sources because the use of primary sources may offer learners the opportunity to organize and analyse their own data. However, time and cost constraints may cause learners to use relevant secondary sources which discuss the possible causes of soil erosion.

4.5.5 Interpreting Data as a Process Skill Applied to the Teaching of Geography

In order to determine the validity of an hypothesis, learners should be taught to analyse the results of their investigations. The development of this skill may empower learners to organise their gathered data and to make generalisations which are supported by their findings. The results of their investigations or experiments may support their *predictions*, *inferences* and *hypotheses*. Data interpretations should provide insight and understanding of the problem.

As an example, the question, *"How is it possible for ice to melt below freezing point?"* entails learners to interpret data provided by the experiment. Zeitler and Barufaldi (1993: 99) observe that interpreting means asking the question - "*What do the data and information mean*"? In the experiment discussed in section 4.5.3, learners are likely to be engaged in the following processes while interpreting data:

- ☐ they will observe that the temperature of the liquid in the beaker is many degrees below freezing point. The act of *observing* is a basic science process skill;

- ☐ they might formulate an incorrect theory that the thermometer does not work and the temperature is actually at the melting point. The use of a thermometer relates to the critical outcome of *using science and technology effectively and critically*;

- they will *record and graph* the temperature at periodic intervals. This process contributes to the development of the basic science process skill of *measuring*. As the task has to be done periodically, this will contribute to the development of the critical outcome in which learners are able to *manage themselves and their activities responsibly and effectively*. Furthermore, this activity contributes to the development of integrated science process skills such as *constructing* a *table of data* and *plotting* a *graph*; and

- They may also form a correct theory that the beaker might contain something other than pure ice (salt in this case). This is an integrated science process skill of *hypothesising* what the beaker might contain. As such, learners may *infer* why the temperature is many degrees below freezing point.

This example shows that the development of one science process skill may contribute to the development of other skills. Furthermore, this example reveals that the interpretation of these data may not be possible without *experimenting*. The following section briefly explains experimenting as a process skill applied to the teaching of geography.

4.5.6 Experimenting as a Process Skill Applied to the Teaching of Geography

Experimenting is an operation that combines all the science process skills that have been discussed above (cf. 2.5.2.10). Scientists combine basic and integrated process skills when experimenting. Children who are given opportunities to experiment, learn to state problems, to test the hypothesis through manipulation and control of variables, and to interpret and present results in the form of reports (Van Aswegen et al. 1993: 18).

Mossom (1989) as quoted in Van Aswegen et al. (1993: 18) has listed the sequence of experimenting steps as follows:

- *stating the problem;*
- *formulating a testable hypothesis;*
- *identifying and controlling variables;*
- *making observations and measurements;*
- *interpreting data; and*
- *communicating procedure and tentative conclusions.*

Sections 4.5.1 to 4.5.6 clearly indicate that it is possible for geography teachers to apply experimenting as a process skill to the teaching of geography. Experimenting requires the integration of all the other science process skills as illustrated in this chapter. Carin (1997: 153 - 211) and Friedl (1991: 124 - 214) have devised various geographical experiments which geography teachers can adapt and demonstrate in their classrooms.

In addition, teachers should also apply basic science process skills to the teaching of mapwork techniques. In South Africa, Grade 12 geography learners complete two examination papers at the end of each year - one paper deals with climatology, geomorphology, ecology, settlement geography and regional geography and the second paper deals exclusively with topographical maps and their respective orthophotos. Thus, it is also important for geography teachers to be able to apply science process skills to the teaching of mapwork. The following paragraphs attempt to indicate in what way teachers can apply basic science process skills to the teaching of mapwork activities.

4.6 BASIC SCIENCE PROCESS SKILLS AND THE TEACHING OF MAPWORK

In South Africa, secondary school geography learners are expected to be fully familiar with all technical aspects of mapwork (cf. 2.7). As a result, it should be possible for geography teachers to teach basic science process skills while they are dealing with mapwork activities. Sections 4.6.1 to 4.6.6, attempt to highlight how this can be done. Basic science process skills which teachers can apply to the teaching of mapwork are observing, measuring, inferring, classifying, predicting and communicating. Learners may be able to use the information on a topographical map to perform these skills. As integrated science process skills are applicable mainly to experimental activities, it may not be possible to apply these skills to mapwork activities.

4.6.1 Observing as a Science Process Skill Applied to the Teaching of Mapwork

Geography learners are expected to observe the title of the topographical map and interpret its meaning (cf. 4.3.4.3). Furthermore, learners should be capable of observing aspects of the map such as the scale of the map, relief and map symbols. The scale of the map is the ratio between the distance between two points on the map and the actual distance between the same points on the ground. This implies that the scale of the map is the relationship between a distance shown on the map and the corresponding distance in reality. It is usually indicated below the map as a linear scale or as a ratio scale. Relief is the form of the physical landscape, including differences in altitude, mountains and valleys, slope, and the shape of the earth's surface.

Map symbols are symbols that are used to depict features of the landscape on the map. Learners are also expected to *observe* and study map symbols closely before they can analyse and interpret the 1: 50 000 topographical maps used in South Africa (cf. 2.5.1.3 and Appendix 14). This process enables learners to observe and read maps, a skill that is likely to empower learners to perform other process skills that may be developed through mapwork activities. Learners could also demonstrate their ability to observe by giving correct answers which are mostly found on the map and the corresponding orthophoto through *observation*. This implies that *observing* is a skill which can be demonstrated by the learners engaged in mapwork activities.

4.6.2 Measuring as a Science Process Skill Applied to the Teaching of Mapwork

In the study of geographical techniques, learners should also learn how to measure lengths, volumes, heights, angles and distances. In most South African topographical maps, two linear scales are drawn to show distances measured in metric units such as kilometres and metres. The teacher may supply exercises that require learners to measure straight line distances and curve line distances.

As indicated in Liebenberg (1986: 55) and Vilakati and McLeod (1994: 26-35), map scales are useful when distances on maps are measured. For instance, to calculate a distance that is linear or straight between two points on the map, the learner should hold a strip of paper against the line. Then, the learner transfers the distance between the two points to the paper and compares the distance with the line scale on the map.

Sometimes the learner may be asked to *measure* the length of a river or a winding road on the map. The learner can do so by using one of the following three techniques:

- The learner should take a piece of thread or string and carefully place it along the winding line on the map. (S)he should mark the starting point and the ending point of the measurement on the string. Then, the learner should pull the string straight and measure the distance between the two marks against the graphical scale on the map;

- The learner can also measure the length of curve lines on the map by breaking up each curve into straight line segments. Then, (s)he should transfer the measured lengths of all the segments, one by one, onto a piece of paper; and

- Lastly, the learner may measure the length of a curve line on a map by setting the point of a pair of dividers accurately at a distance of 0,5cm apart. Then, (s)he should 'step off' the entire length of the line, counting the "steps". If say, the learner counts 40 steps, the total line distance will be 20 cm which is then compared to the line scale on the map.

These activities show that *measuring* skill is a demonstrable outcome. Learners could be seen engaged in measuring activities while dealing with mapwork activities. Engagement in this skill may enable learners to *infer* and *predict* how long it may take them to move from one point to another.

4.6.3 Inferring as a Science Process Skill Applied to the Teaching of Mapwork

An inference is an explanation or interpretation of an observation (Rezba et al. 1995: 70). The process of interpreting and explaining symbols indicated on the map may develop and promote the skill of inferring. Learners are likely to develop other skills that are necessary to make proper inferences based on map observation. Suppose, for an example, learners *observe* a dense drainage pattern and several perennial rivers on the map. Learners may *infer* that the area depicted on the map is a high rainfall region. If they *observe* that the map has several dams, they are likely to *infer* that the area experiences inadequate rainfall. Thus why a need to store water exists. Furthermore, if learners *observe* furrows ploughed along a slope that follows the contours, they are likely to *infer* that furrows are ploughed along the slope in order to prevent erosion during the rainy season.

These examples indicate that inferring is a demonstrable science process skill because learners are able to interpret and explain features observed on the map. They are able to recognise patterns on the map and make proper inferences based on past observations.

Most mapwork activities compel learners to give meaning to what they observe on the map. Giving meaning to the observation may require learners to invoke what they already know from past experiences or previous knowledge. Suppose, for example the topographical map consists of many solid blue lines and orchards. If learners are asked to indicate if most of the streams and water courses are perennial or seasonal, learners are likely to *infer* that the streams and water courses are perennial.

As a result of past knowledge, learners would have indicated that solid blue lines instead of blue dotted lines, represent perennial rivers. Furthermore, orchard symbols on the map cause learners to infer that commercial farming is practised in that area. Consequently, learners are also likely to infer that commercial farming is valuable where an adequate irrigation water system exists.

4.6.4 Classifying as a Science Process Skill Applied to the Teaching of Mapwork Techniques

Mapwork activities that may develop and promote the skill of classifying may include the classification of:

- geographical phenomena depicted on a map into natural features and man-made features. On the map, natural features are brown in colour whilst man-made features are black;

- rivers and water courses into perennial rivers and non-perennial rivers. On the map, perennial rivers are indicated by solid blue lines whilst non-perennial rivers are shown by blue dotted lines;

- rivers' drainage patterns into dendritic, trellis, radial, rectangular and deranged patterns;

- slopes into gentle slopes, steep slopes, vertical slopes, stepped slopes, uneven slopes, uniform slopes, convex slopes and concave slopes.

- river density into low density (coarse texture), medium density (medium texture), high density (fine texture) and extremely high density (superfine texture);

- farming into subsistence farming or commercial farming. Commercial farming is again classified into crop farming, livestock farming, horticulture and forestry;

- settlements into rural or urban settlements;

- rural settlements into dispersed or nucleated settlements;

- rural settlements into an isolated farmstead, a hamlet or a village;

- urban settlements into a town, a city, a metropolis, a conurbation or a megalopolis;

In order to foster the development of the *classification* skill, teachers should request learners to *classify* what they observe on the map according to one or more of the above-mentioned classifications. The implication of this activity is that the ability to *classify* effectively is determined inter-alia by the appropriate application of the criteria. *Classification* is a demonstrable science process skill as learners could demonstrate their competence of mastery by *classifying* objects and events on the basis of *observable* characteristics. The following paragraphs discuss predicting as a skill applied to mapwork.

4.6.5 Predicting as a Science Process Skill Applied to the Teaching of Mapwork

Geography teachers may require learners to make *predictions* when dealing with topographical maps. This process involves learners to say what may happen in the future. This is possible if learners know the situation prevailing at the present time. As every topographical map attempts to show physical and man-made surface features which are found in that area, it is assumed that these features may exist until a new map is compiled. Hence learners should be able to scrutinize the map carefully in order to imagine what would happen in the future. Consider the following example adapted from Liebenberg (1986:154) based on a 3318CD Cape Town topographical map (Appendix 14).

> *Cape Town is notorious for a south-easterly wind which sometimes reaches gale force during the summer months. Hence it is sometimes referred to as the 'Black South Easter'. Where would most people settle in Cape Town if they had a choice and could not tolerate the wind?*

This question would require learners to use the map and existing knowledge about Cape Town. Cape Town's central business district, and the suburbs of Oranjezicht and Vredehoek are not protected from the South-Easter as they are saddled between Devil's Peak and Table Mountain which 'funnels' the wind over the city. Furthermore, the air forced upwards by Table Mountain descends over the city and its surrounding residential areas, and Camps Bay. This causes local turbulence which may discourage people from living in these areas. Actually, Sea Point is the only area which is really shielded from the South-Easter. Using these logical deductions, learners are likely to *predict* that, most people would prefer to settle at Sea Point if they have a choice.

Effective prediction can be taught through encouragement of learners to observe features which are depicted on the map. After the *observation*, learners should be able to explain what patterns they expect to observe in the future (*prediction*). This implies that prediction is also a demonstrable activity as it starts with observation and end with reasoned statements on occurrences that might happen in the future.

The application of the predicting skill to the teaching of mapwork is crucial as it encourages learners to make informed predictions rather than guess work. Prediction also implies that learners understand something as they are afforded opportunities of choosing between contradicting explanations. Learners are likely to choose between the contradicting explanations by testing their ideas through logical reasoning as shown in the example. After testing their ideas and arriving at predictions, learners are supposed to show that they have mastered this process by communicating their predictions and any other relevant information.

4.6.6 Communicating as a Science Process Skill Applied to the Teaching of Mapwork

Topographical maps allow learners to interpret physical and man-made surface features. This implies that learners should be capable of communicating geographical phenomena which they observe on maps. Learners should also be taught to communicate the information accurately using colours and shapes of geographical features depicted on the map (cf. Appendix 14). In mapwork activities, learners are taught to use the tools of communicating such as graphs, symbols, numbers, oral descriptions, written language, data tables, drawings and charts. Learning to use these communication tools enables learners to make good decisions about how to communicate observation and ideas (Rezba et al. 1995: 19). This implies that map work activities also contribute to the development of the critical outcome of *communicating effectively using visual, mathematical and language skills*.

A map is a symbolic representation of realty. Topographical maps have a title indicating the exact location of the map (cf. 4.3.4.3). Consider for example the following map code, 3318CD Cape Town. Learners should be able to interpret the title of this map by following the steps which were shown in section 4.3.4.3. Subsequently Cape Town region is located at grid reference 33°S and 18°E. Furthermore, the map is positioned in the large block C and the small block D .

Cartographers also communicate phenomena on the map through symbols (cf. 2.5.1.3). Learners should be able to indicate what each symbol represents by referring to the map's key. The map also has a scale which learners may use to calculate relative distances, gradients and areas. Geography teachers could also develop communication skills in learners by giving them opportunities to draw map sketches. After drawing map sketches, learners may also give map descriptions to someone in the class and have them locate and recognize the desired phenomena (Rezba et al. 1995: 21). If most learners can use the map and its descriptions to find and recognize required phenomena, it may imply that the role of the map in the development of communication skills is effective. This is a demonstrable outcome because learners who are engaged in mapwork activities may *communicate* the information depicted on the map to their peers or to their teacher.

4.7 CONCLUSION

Science process skills can be advantageously applied to the teaching of geography, however, science process skills should not be applied in isolation of knowledge. The discussion in this chapter has indicated the importance of knowledge as a foundation to the development and understanding of science process skills.

The application of these skills may continue to be clarified through practice, reflective thinking and research. In this regard, Chapter 4 suggests that teachers should consider Piaget's stages of intellectual development before asking questions in class that require learners to apply science process skills. Furthermore, teachers should also follow the same process before providing learners with science process tasks that they should perform. Consideration of Piaget's theory might enable teachers to design activities that might be suitable to the learners' particular stage of cognitive development.

In conclusion, this chapter focussed on two aspects, namely, Piaget's theory of learning and its role in the development of science process skills in the geography curriculum. The chapter also explored several examples and activities for teachers to apply to their everyday teaching. The following chapter reviews the data processing procedures and the description of the statistical techniques applied in this study.