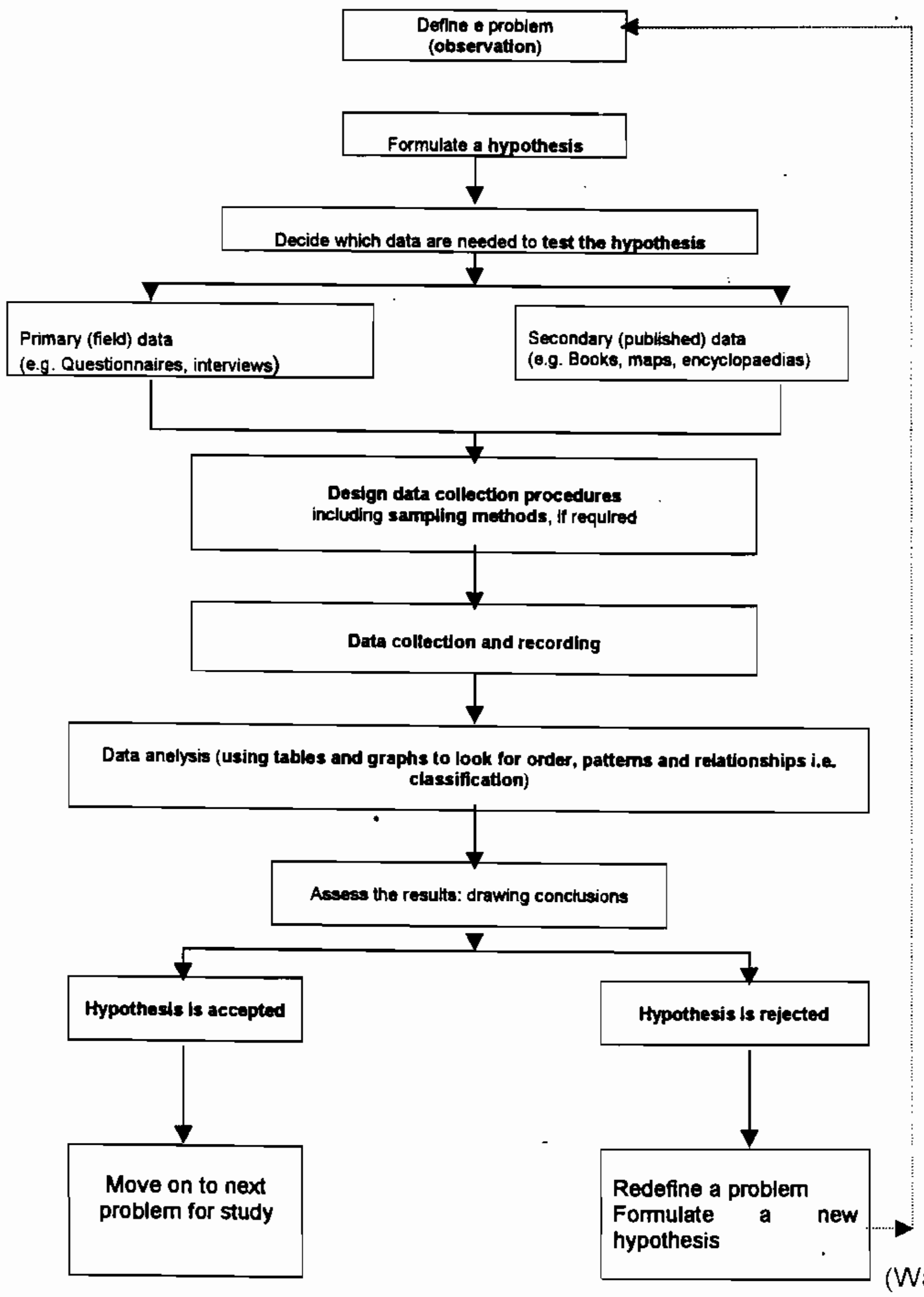
Figure 2.7 Scientific Inquiry: Hypothesis Testing



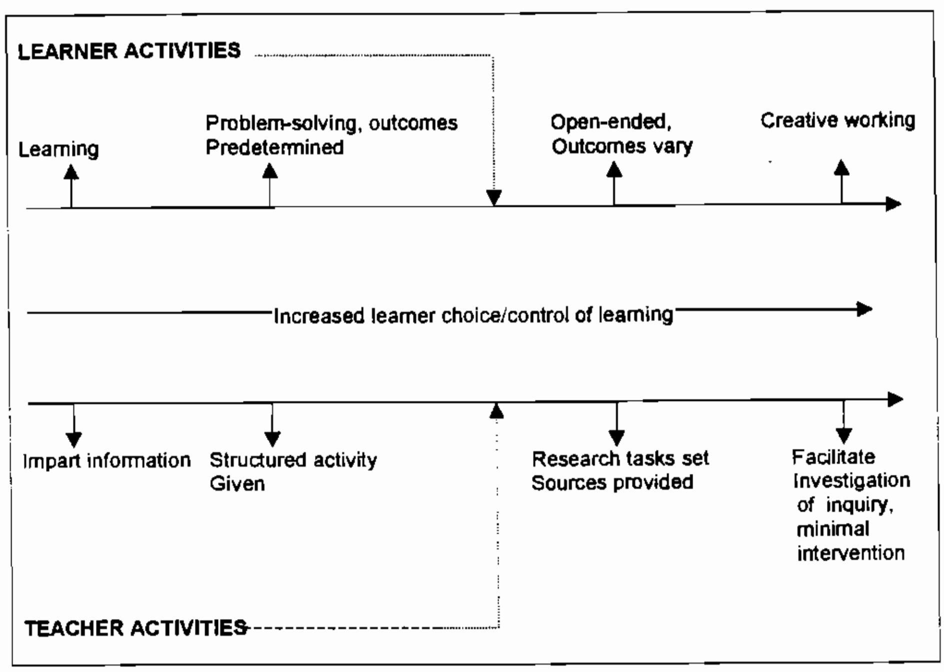
(Waugh 1990: 285)

In any inquiry-based classroom the characteristics of outcomes-based education, an educational approach which is discussed in the next chapter, are likely to be found. According to Greasley et al. (1992: 7) the characteristics of inquiry-based learning are:

- *knowledge and understanding are developed by a structured questioning approach;*
- *an emphasis on problem solving;*
- *collaborative group work;*
- *decision making;*
- *the identification and development of values and attitudes;*
- *the exploration of a range of viewpoints; and*
- *open-ended outcomes to inquiry.*

These activities develop discovery and inquiry thinking abilities and process skills of science that enable learners to obtain information. Following is Figure 2.8 which expresses inquiry teaching and learning approaches as a continuum. Inquiry geography places much emphasis on learners' activities which are at the top of the continuum.

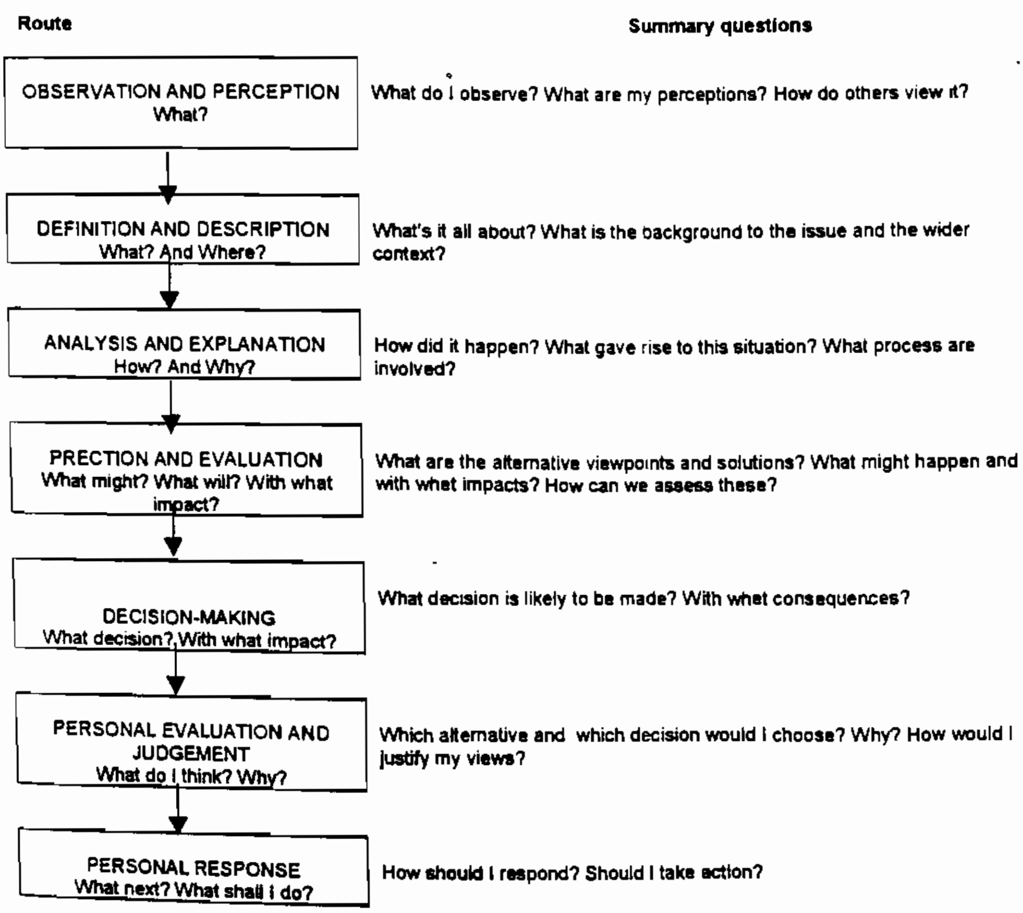
Figure 2.8 Inquiry Teaching and Learning Approaches



(Adapted from Greasley <u>et al</u>. 1992: 7)

In Figure 2.8, learners are encouraged to solve problems to which the answers are different and open-ended. Learners are able to arrive at different solutions as they make use of their own initiative and are creative in order to produce original reports. The role of the teacher is to set research tasks, to help learners to locate relevant sources and to guide and facilitate the investigations. It is important that the teacher should also encourage the learners to identify and define their own problems with his/her accompaniment. This is likely to stimulate learners' thinking processes, divergent and creative responses, hence Figure 2.9 below which illustrates a summary of the route of inquiry and inquiry questions.

Figure 2.9 The Route of Geography Inquiry



(Lambert and Baldersone 2000: 61)

Figure 2.9 shows a summary of the route for inquiry and inquiry questions. The implication of this summary is that inquiry teaching and learning, science process skills and outcomes-based education are associated and linked as illustrated on the next page.

Figure 2.9 also illustrates that route for geographical inquiry incorporates science process skills and outcomes. This route for inquiry also provides a framework within which learners can develop and demonstrate science process skills which are useful when investigating a problem or an issue.

A review of Figures 2.9 and 2.10 indicate key questions which geography teachers can ask of their learners. Answering each and every question would inevitably involve some consideration of science process skills. Engagement in any science process skill may lead to an outcome as shown in Figure 2.10. Hence, Figure 2.10 supplies a framework within which teachers can apply science process skills to the teaching of geography. Furthermore, the figure also provides learning experiences for learners by involving them in science process skills. As shown in Figure 2.10, these inquiry skills could be demonstrated and achieved as outcomes.

It is also implicitly implied by Figure 2.10 that the skills, inquirers use are probably science process skills. These skills are probably at the heart of inquiry teaching and inquiry learning. Therefore, science process skills or inquiry skills should be included in all lessons irrespective of the subject (Carin and Sund 1989: 67). Following is Figure 2.10.

Figure 2.10 The Route for Geography Inquiry, Science Process Skills and Outcomes

Science Process Skills	**Route for Geographical Inquiry and Key Questions**	**Outcomes** Learners should able to
Identifying and **observing** a question, issue Or problem arising from interaction of people and their environment.	OBSERVATION AND PERCEPTION What?	Identify and **observe** a question, issue or problem arising from interaction of people and their environment.
Define and **communicate** the question, issue or problem. **State hypotheses** where appropriate. Decide on data and evidence to be collected. **Collect, classify** and describe data and evidence.	DEFINITION AND DESCRIPTION What? and Where?	Outline and define the question, issue or problem. **State hypotheses** where appropriate. Decide on data to be collected. Collect, **classify** and describe data and evidence
Organise and analyse data. Move towards providing answers and explanation. Attempt to **accept, reject or modify hypotheses.**	ANALYSIS AND EXPLANATION How? and Why?	Organise and analyse data. Provide answers and explanation. **Accept, reject or modify hypotheses.**
Evaluate results of inquiry. Attempt to make **predictions,** to formulate generalisations and if possible to **infer** and **construct theories.** Propose alternative courses of action, and **predict** possible consequences.	PREDICTION AND EVALUATION What might? What will? With what impact?	Evaluate results of inquiry. Make **predictions**, formulate generalisations and if possible to **infer** and **construct theories.** Propose alternative courses of action, and **predict** possible consequences.
Recognise the likely decision given the factual Background of the problem **(identifying & controlling variables, acquiring & processing data, analysing the investigation).** Identify the probable environmental and spatial consequences **(Prediction and reject, accept or modify the hypotheses).**	DECISION MAKING What decision? With what impact?	Recognise the likely decision given the factual Background of the problem. Identify the probable environmental and spatial consequences.

PERSONAL EVALUATION AND JUDGEMENT
What do I think? Why
Determine which solutions are important.
Access the impact of the solutions on the situation.
Consider how one would defend and justify the solutions.

PERSONAL RESPONSE
What next? What shall I do?

DECIDE WHETHER AS A RESULT OF THIS INQUIRY
- to take individual or group action.
- to help initiate action on this issue by contacting those in positions of power.
- to take action to change aspects of personal behaviour which may affect future actions.
- to take no immediate action, but to follow further inquiries in order to test out one's feelings.

(Lambert and Balderstone 2000: 74)

As Figure 2.10 has indicated that science process skills can be achieved and demonstrated as outcomes, the researcher is compelled to ask the following questions:

- *What are science process skills?*
- *Are science process skills applicable to geography?*

The following sections attempt to provide answers to these important two questions.

2.5 SCIENCE PROCESS SKILLS

Millar and Driver (1987:39) have identified three domains for 'process science'. These domains are the processes applied to investigate phenomena of the world, intellectual processes applied to learn science and teaching processes that are adopted in the classroom. This study is concerned with science process skills that are applied when a problem or an issue is investigated. It is also concerned with the application of these skills to the teaching of geography in the classroom.

An investigator uses the science process skills to find solutions to the investigated problems. This research encourages teachers to apply science process skills to the teaching of geography because processes develop learners' scientific skills through engaging them in scientific activities. Proponents of science process skills claim that knowledge-based curriculum has failed (Wellington 1989: 8). It is argued that the content-led approach has failed because only few science learners can master scientific knowledge as the world is experiencing an explosion of information. Opponents of content-based curriculum question the ability of teaching facts in the age of information technology. They propose that learners should be taught how to retrieve information from information technology data bases instead of facts.

They claim that facts become outdated quickly. Learners should be taught transferable practical skills which are more relevant than knowledge (Wellington 1989: 7-15). Millar (1991: 51) has classified 'practical skills' into three categories, namely, *general cognitive skills* which some researchers claim cannot be taught, *practical techniques* and *inquiry tactics* which can be taught and improved. Figure 2.11shows the differentiation of the general category of 'practical skills'

Figure 2.11 Sub-categories of 'Practical Skills'

Practical skills'

General cognitive *processes*	Practical *techniques*	Inquiry *tactics*
(* observe, * classify, * hypothesise, ...)	(Measure temperature, air pressure, wind speed, wind direction, air humidity, ...)	* repeat measurements, * draw graph to see trend in data, * identify variables to alter, measure, control, ...)

←(cannot be taught) → ← (can be taught and improved) →

(Millar 1991: 51)

The research study propagates for the application of all these 'practical skills' (cf. Chapter 4). These skills are collectively known as science process skills (cf. 1.6.3, 1.6.4 and 1.6.5). Funk et al (1979: 1) and Rezba, Sprague, Fiel, Funk, Okey and Jaus (1995: 1) have noted that these skills are either classified as basic skills or integrated skills.

The basic science process skills are observing, classifying, communicating, measuring, predicting, and inferring. The integrated science process skills are identifying variables, constructing tables of data, constructing graphs, describing relationships between variables, acquiring and processing data, analysing investigations, constructing hypotheses, operationally defining variables, designing investigations and experimenting.

It is therefore imperative that learners should master basic skills before they can learn integrated skills. For example, learners may not be able to describe the relationship between variables such as temperature and rainfall, without being able to observe the temperature of the day through any of the senses. This is because a basic skill such as *observing* is the foundation of all other skills (Millar 1991: 46). Both basic and integrated skills provide opportunities to the learners to apply critical thinking activities in whatever way they do. The following section briefly explains basic and integrated science process skills. Chapter 4 has highlighted, by means of examples, how these skills could be applied to the teaching of geography

2.5.1 Basic Science Process Skills

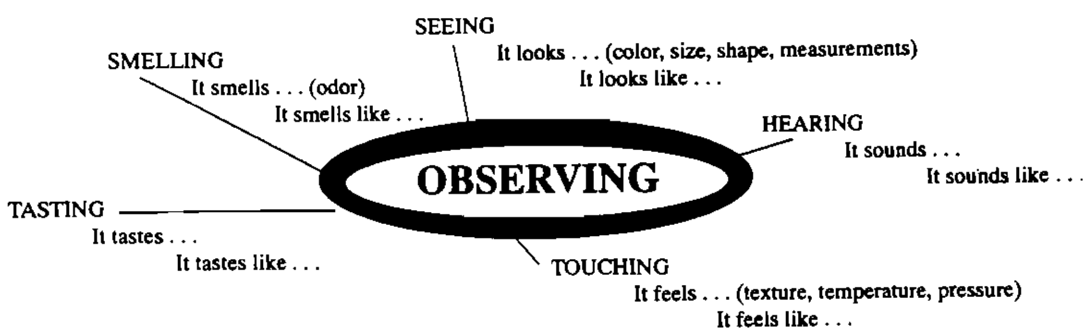
From the foregoing paragraph it is clear that basic science process skills involve less reading of content and more sciencing and doing. Such skills also enable learners to be actively involved in the learning process. Learning becomes interesting and learners become more stimulated and motivated. All other science process skills are based on the skill of observing (Rezba et al. 1995: 1).

2.5.1.1 Observation

Observation is the primary way in which people obtain information about their environment through the five senses, namely, sight, smell, touch, taste and hearing (Rezba et al. 1995: 3). which is classified as qualitative observation. Sometimes learners can use a standard unit of measure for more precise information than the senses alone can provide. This is quantitative information which helps in the communication of specifics and provision for comparisons. This type of observation requires instruments such as rulers, metre sticks, balances, calibrated cylinders or beakers, and other instruments, and it is called quantitative observation. The knowledge acquired through observation leads to the development of inquiry and questioning attitudes about the environment. Learners start to investigate environmental problems or issues. Observation may lead to the development of other basic skills such as communicating, predicting, inferring and classifying which are done qualitatively and measuring which is done quantitatively.

Millar (1991: 47) argues that observing is a skill that every individual possesses. (S)he therefore, questions why observation needs to be taught *per se*. The researcher, however, is of the opinion that the most important factor is to encourage learners to make relevant observations in order for them to become scientific observers. Thus, the ability to make relevant observations must be developed through engaging learners in observation activities. Furthermore, learners engaged in observational activities are likely to develop the ability to observe geographical phenomena critically. Figure 2.12 indicates senses that are used when properties of an object are observed.

Figure 2.12 Five Senses Used to Observe Objects



(Rezba et al. 1995:4)

A review of Figure 2.12 indicates the five senses that people apply when exploring the properties of any object or substance. These senses understandably could also be used to observe geographical features (cf. 4.4.1). After observing, individuals are like to classify the observed features, hence the discussion in the next section.

2.5.1.2 Classification

The environment comprises a number of objects, events and living things. Classification requires people to organize their observations in ways that carry special meaning (Martin et al. 1994: 12). People classify these in order to comprehend them. Classification takes place through observing similarities, differences and interrelationships (cf. 4.4.4). Consequently, classification is likely to lead to concept formation and communication.

2.5.1.3 Communication

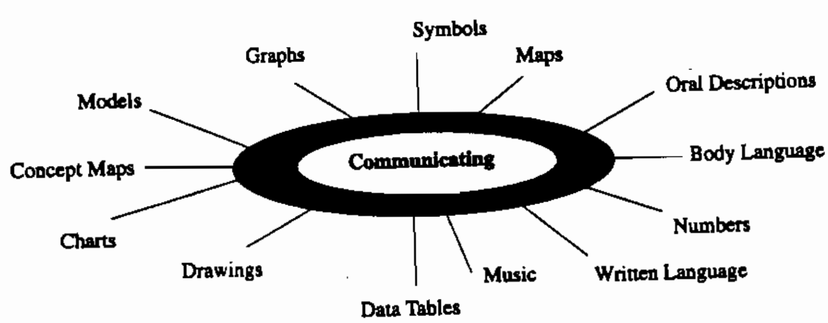
Communication is important in whatever people do. Teachers communicate knowledge, ideas and instruction to their learners. Learners also communicate knowledge and ideas to their teachers and peers. Figure 2.13 in the next page depicts communication tools such as graphs, charts, maps, symbols, diagrams, mathematical equations, visual demonstration and written and spoken words which are used to communicate vital information. These tools of communicating can be applied to the geography curriculum (cf. 4.4.6). Teachers encourage their learners to use these forms of communication to convey the findings of the problem investigated clearly, precisely and concisely. Funk et al. (1979: 26) maintain that for one to communicate effectively one should:

- *describe only what one observes (see, feel, smell, hear and taste) rather than what one infers about the object or event;*

- *make ones description brief by using precise language;*
- *communicate information accurately using as many qualitative observations as the situation may call for;*
- *consider the point of view and past experience of the person with whom one is communicating;*
- *provide a means for getting "feedback" from the person with whom one is communicating in order to determine the effectiveness of their communication; and*
- *construct an alternative description if necessary.*

Following is Figure 2.13 which shows some instruments which learners can employ to communicate the results of their inquiry.

Figure 2.13 Communication Tools



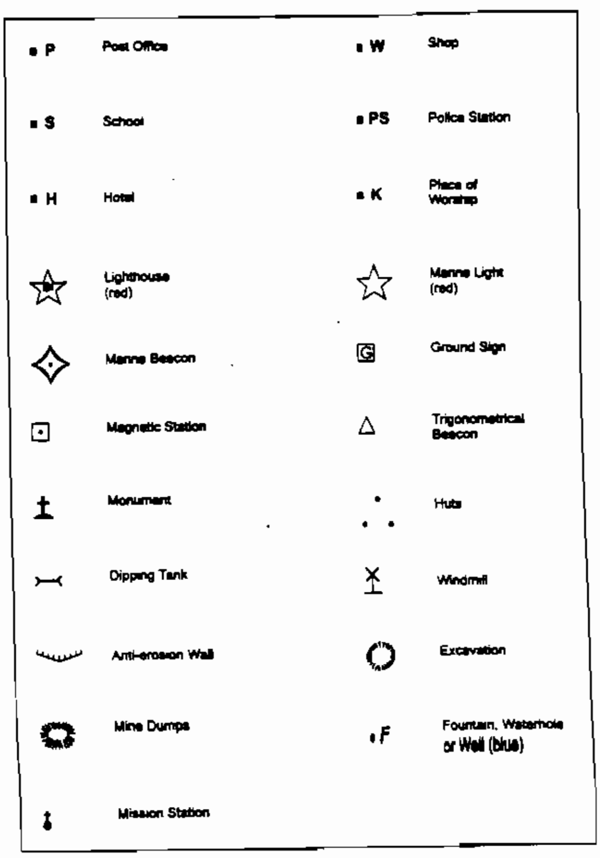
(Rezba et al. 1995: 19)

Figure 2.13 depicts communication instruments which are essential in geography education. For instance, learners need to master map work skills which are important in any map interpretation (cf. 4.6). Maps communicate important information about a country, region or an area as they are symbolic representation of reality on the actual ground. Geographers use the conventional map symbols to communicate the most significant geographical information found on the actual ground.

These symbols are used in the South African 1 : 50 000 topographical map series. A topographical map is a map showing physical and man-made surface features (Blackbeard 1992: 3). There are three types of map symbols, namely, point symbols, line symbols and area symbols (Carstens 1991: 137 and Liebenberg 1989: 61). Different colours are conventionally used for the different symbols. For instance, green represents vegetation, blue is for water, brown is for natural or physical features and black is for any man-made feature. The reader is requested to compare these symbols with the ones appearing on 3318CD Cape Town topographical map for the actual colours used (Appendix 14). Following are point symbols which are drawn on topographical maps.

- ☐ **Point symbols**

Figure 2.14 Point Symbols

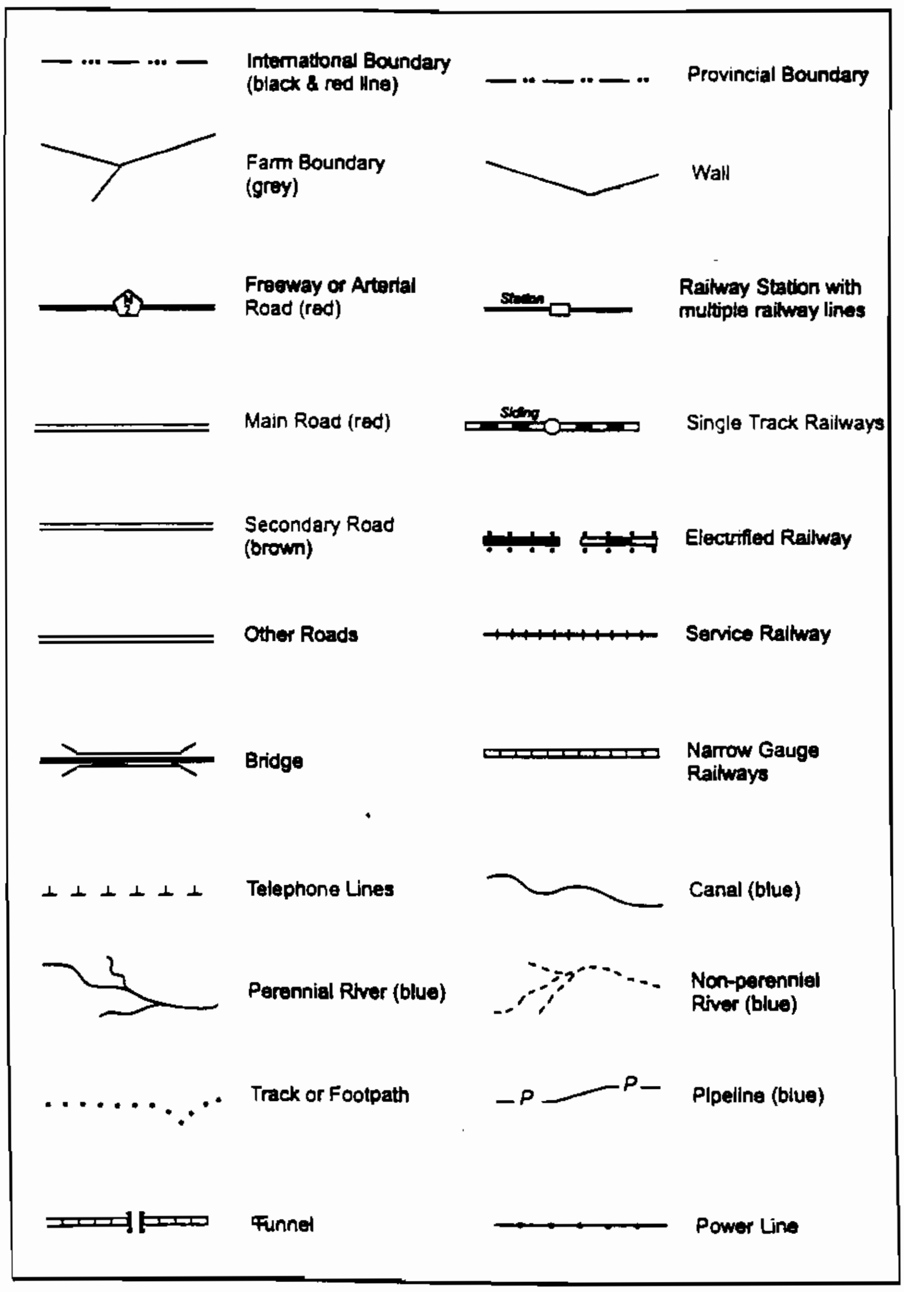


(Carstens 1991: 138)

Figure 2.14 shows the most important point symbols which appear on 1 : 50 000 South African topographical map series. The position of the symbol on the map corresponds with the actual location of the feature on the ground. Following are line symbols which are found in topographical maps.

☐ **Line symbols**

Figure 2.15 Line Symbols

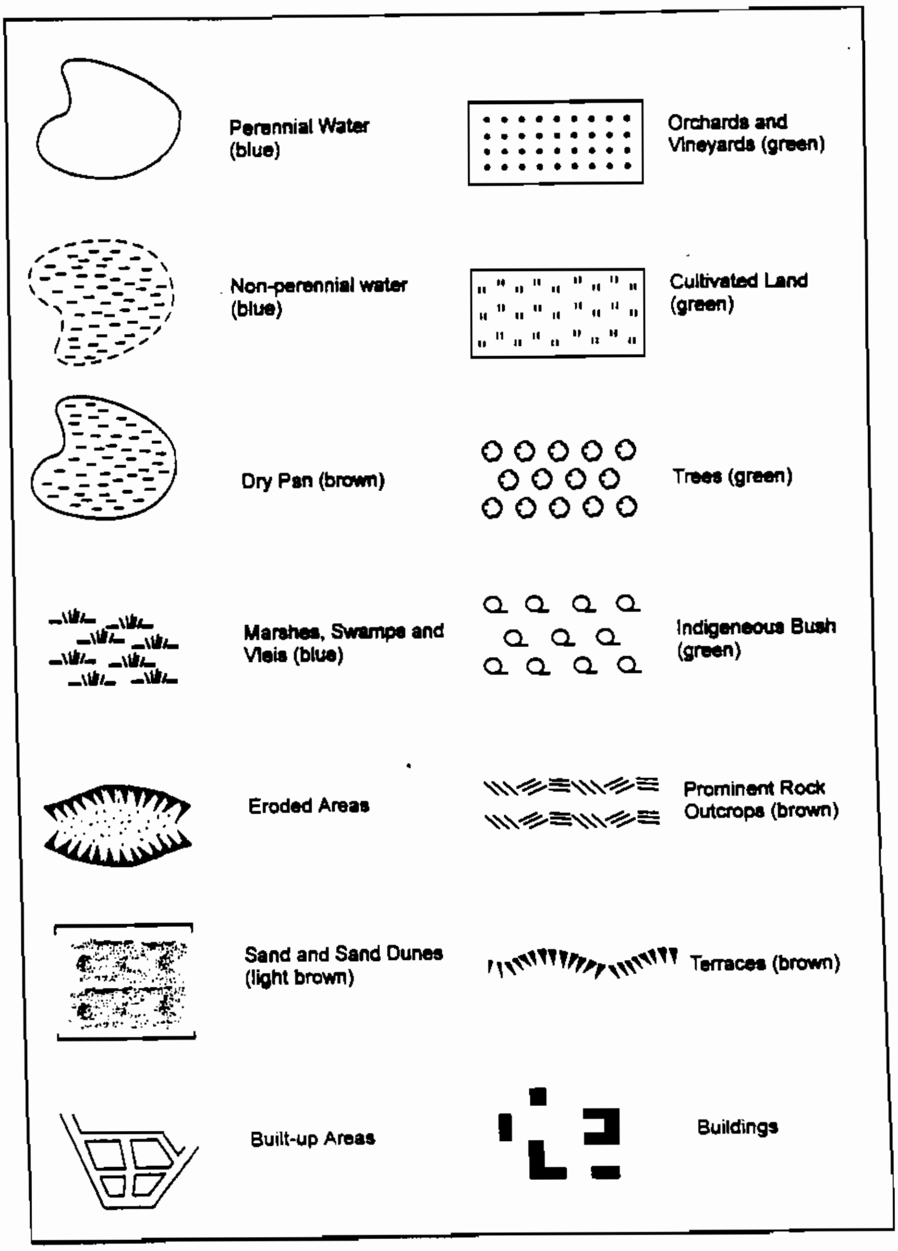


(Carstens 1991: 139)

Figure 2.15 depicts examples of the most important line symbols which appear on 1 : 50 000 South African topographical map series. Line symbols illustrate linear phenomena such as roads, power lines, telephone lines, canals railway lines and boundaries. Following are area symbols which are found in topographical maps.

- **Area symbols**

Figure 2.16 Area Symbols



(Carstens 1991: 140)

Figure 2. 16 shows examples of the most important area symbols which appear on 1 : 50 000 South African topographical map series. Area symbols depict phenomena such as lakes, dams, pans, cultivated fields or pans.

Geography learners should be able to make a rough sketch of a map and draw all these symbols. Furthermore, the colours used for these symbols on the topographical make these symbols easier to spot. After mastering these conventional symbols, geography learners are also expected to measure and calculate distances amongst various symbols in metres and kilometres, hence the discussion in the next section.

2.5.1.4 Measurement

People do different kinds of measurement in their environment daily. They measure angles, numbers, sizes, lengths or distances, volumes and mass. The learning and practice of skills needed to do these measurements are essential for learners to be able to think in metric terms.

Measurement enhances thinking by adding precision to observations, classifications and communication (Martin et al. 1994: 13). Some of the measuring activities applicable to geography are calculation of map scales, distances, directions, bearing, declination; the measuring of air pressure, air temperature, dew point temperature, amount of precipitation, amount of cloud cover and so on (cf. 4.4.2 and 4.6.2).

Measuring makes it possible for a person to make a prediction about the occurrence of geographical phenomena. For instance, observing and measuring the weather conditions which prevail in a specific area may enable a meteorologist to predict if it would be hot, cool or cold and if it would rain or not. Hence *observing* and *measuring* are demonstrable and achievable as outcomes.

2.5.1.5 Prediction

Funk et al. (1979: 57) define prediction as ..."*a forecast of what a future observation might be*." Predictions are types of thinking that require peoples' best guesses based on the information available to them (Martin et al. 1994: 13). Geographers are supposed to be able to forecast weather and the occurrence of other phenomena like drought, floods, tornadoes, volcanoes and hurricanes. Meteorologists predict weather in advance of its actual occurrence. They base their predictions on accumulated observations, analysis of information, and prior information. These are the foundations of prediction.

Thus, one should be able to predict after the mastery of other skills such as observing, inferring and classifying. Information gained through the senses (observation) and inference enables one to forecast what a future observation will be (prediction).

Observation of similarities or differences of geographical phenomena enables people to impart order in their environment. It is argued that "*order in our environment permits us to recognize patterns and to predict from the patterns what future observations will be*" (Funk et al. 1979: 57). Prediction is a skill which can be applied to the geography curriculum (cf. 4.4.5).

Prediction is interconnected with inference as they are all based on information gained through the senses. For instance, a prediction is a focus of what a future observation will be, whilst an inference is an explanation for the observation (Rezba et al. 1995: 91). The following section discusses inferences.

2.5.1.6 Inferences

Inferences are conclusions about the cause of an observation. Direct observation of objects or events enables people to suggest something, to interpret and explain things and activities happening in the environment. For instance, an explanation or interpretation of an observation is indeed an inference (Funk et al. 1979: 72). Furthermore, inferences enable one to formulate hypotheses which may influence one's understanding of one's observations. In order to infer, people use their past experiences and link them with the new ones. For instance, a person is able to infer that it rained with thunder and lightning by reflecting on the size and type of the cloud. This implies that inferring is an everyday activity which can be applied to the geography curriculum (cf. 4.4.3 and 4.6.3).

Mastery of basic science process skills prepares the learner to learn new skills that may lead to experimenting (Rezba et al. 1995: 117). These are integrated science process skills that enable learners to explore, investigate and discover knowledge. Hence, investigation tasks are likely to promote the development of integrated science process skills in learners.

2.5.2 Integrated Science Process Skills

Integrated science process skills rely on learners' capabilities to think at a higher level and to consider more than one thought or aspect at a time (Martin et al. 1994: 13). These skills are more complex than basic skills. Just as in basic science process skills, integrated science process skills are used in problem solving. They are the immediate tools which could be used when seeking solutions to problems (Funk et al. 1979: 83). The following section briefly discusses the skill of identifying variables.

2.5.2.1 Identifying Variables

What is a variable? Fraenkel and Wallen (1996: 51) point out that "a *variable is a concept - a noun that stands for variation within a class of objects, such as chair, gender, eye colour, achievement, motivation, or running speed.*" It is something that can vary or change (Fraenkel and Wallen 1996: 51 and Rezba et al. 1995: 123). Liebenberg (1986: 156) regards a geographical variable as a geographical phenomenon, whose characteristics change from place to place or time to time. For example, *"The temperature for an area (Welkom) is influenced by the time of the day."* For instance, on the same day it can be -2°C at 02:00 and 18°C at 14:00.

The skill of identifying variables is essential when one is conducting an investigation. For a person to be able to plan and carry out an investigation, (s)he has to identify variables as an independent (manipulated) variable or a dependent (responding) variable and as a categorical or a quantitative variable (Gay and Airasian 2000: 148; and Fraenkel and Wallen 1996: 51-55). In the example given above, *time* is the **independent variable** whilst *temperature* is the **dependent variable**.

A quantitative variable assigns number to different geographical phenomena. For instance, today's temperature is 25°C and yesterday's rainfall was 20 mm. Categorical variables are always qualitative in nature. They do not vary in degree, amount, or quantity (Fraenkel and Wallen 1996: 52). For example, dark grey clay soil, light brown loam soil and red brown sand soil are categorical variables. Identification and manipulation of variables is a skill that can be applied to the geography curriculum (cf. 4.5.3). Learners who can identify variables should also be able to construct a table which shows data for the relevant variables, hence the discussion in the next section.

2.5.2.2 Constructing a Table of Data

When identifying the variables, the information on the variables can be presented in tables. One is able to establish trends and patterns by analysing the tables (Rezba et al. 1995: 153), which could be the measurements of temperature, rainfall, time or volume. What is important. is that when constructing a table of data, a person should record the independent variable on the first row and the dependent variable on the second row. If manipulated variables are listed in order of magnitude, one is able to establish their pattern of change. This is also applicable to the responding variables. The following is an example of a table for hypothetical mean annual rainfall amounts in Cape Town:

Table 2 .1 Mean Annual Rainfall in Cape Town over a Period of 12 Months

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Annual Rainfall in mm	12,6	10,3	18,4	60,6	77,1	82,4	94,8	68,9	43,0	28,6	20.3	10,2

In Table 2.1, months are independent variables whilst the mean annual rainfall figures are dependent variables. Furthermore, in order to have information as indicated in Table 2.1, learners should initially be able to demonstrate their ability to observe a rain gauge and record the amount of rainfall daily. Secondly, they should be able to calculate the monthly means of rainfall. Ultimately, the outcome is that learners should be able to observe and record the measurements of time, temperature, rainfall or volume.

Furthermore, when given a written description of the measurements made during an investigation, learners should also be able to construct a table of data. They should also be able to write pairs from a table of data, and ultimately to match data pairs with points on a graph. As illustrated in Table 2.1, this skill of organizing data in a table can be applied to the geography curriculum. The skill of organizing data in a table can also in turn promote the skill of plotting a graph.

2.5.2.3 Plotting a Graph

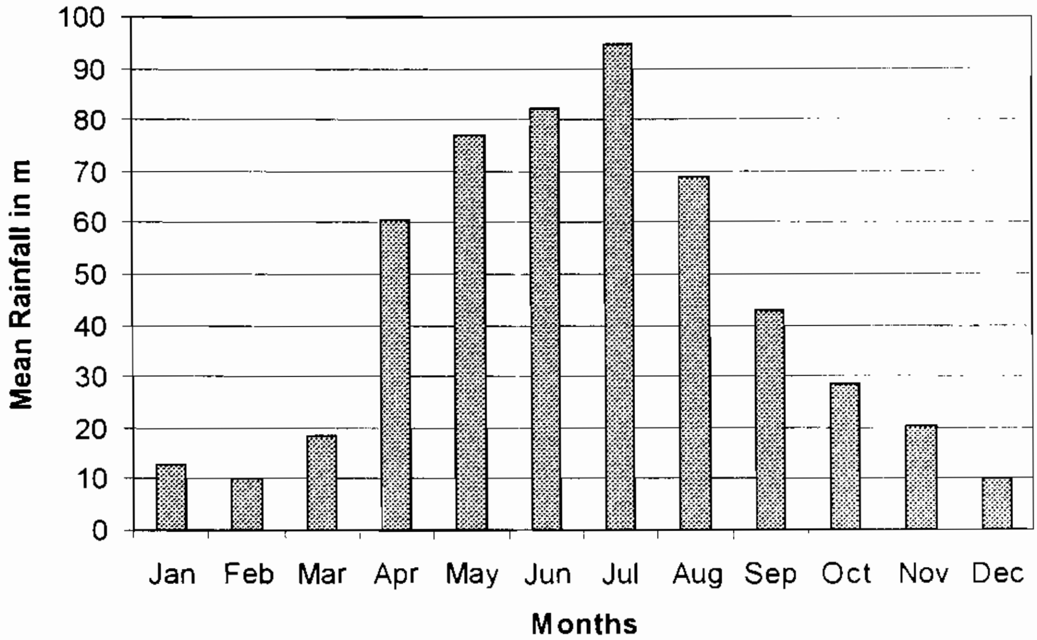
It has already been established that one can employ various forms of communication to report the findings of an investigation (cf. 2.5.1.3). One of these forms of communication involves drawing a graph instead of using a spoken or written message. A person is able to construct a graph when provided with a description of an investigation and a table of data.

Geographers draw graphs and diagrams to represent temperature figures, population figures, economic production figures or rainfall figures. These types of graphical representation may also appear in newspapers and magazines. In order to understand and attach meaning to what is happening around them, people should be able to interpret graphs. Liebenberg (1986: 156) argues that graphs and diagrams enlighten the hidden qualities of the data and make the message easier to understand. Three types of graphs or diagrams which geographers may use to depict the data in a table have been identified. Examples of diagrams and graphs are the bar graph or histogram, the line graph and the segmented circle or pie diagram.

- **The bar graph**

The data in Table 2.1 can be used to compile the following bar graph.

Figure 2.17 Bar Graph: Mean Annual Rainfall in Cape Town over a Period of 12 Months



Liebenberg (1986: 156) maintains that in geography, the bar diagram is used for:

- *comparing the subdivisions of the same geographical variable with one another;*
- *comparing a geographical variable in terms of different time intervals or periods; and*
- *comparing a geographical variable in terms of different places.*

A review of Figure 2.17 indicates that the wettest month in Cape Town is July. The month with the lowest rainfall is December and rainfall decreases from July to December. In geography bar graph are usually used to plot rainfall figures.

- **The line-graph**

In geography, the line-graph is used to indicate changes in a geographical variable over a period of time (Liebenberg 1986: 156). In geography, it usually used to plot temperature figures. For example, the following table which shows average monthly temperatures for Bloemfontein can be used to draw a line graph.

Table 2.2 Average Monthly Temperatures in Bloemfontein over a Period of 12 Months

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average temperatures in °C	27	24	25	15	11	8	7	10	17	20	24	29

The line graph can be plotted as follows:

Figure 2.18 Line Graph: Average Monthly Temperatures in Bloemfontein over a Period of 12 Months

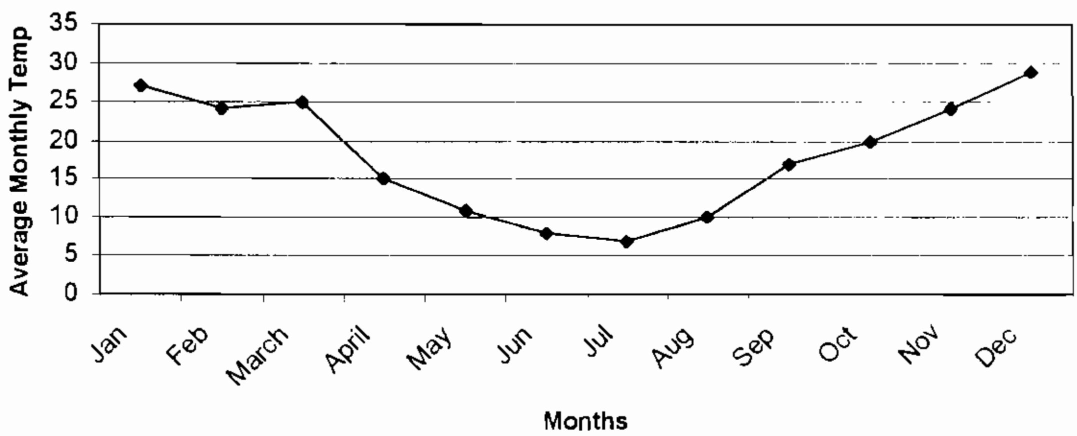


Figure 2.18 clearly indicates that December is the hottest month in Bloemfontein and July is the coldest month. It is also apparent that the temperature increases from August to December.

Furthermore, as illustrated in both Figures 2.17 and 2.18, the learner should be able to decide where independent and dependent variables must be placed on the axis of the graph. The independent variables are written along the x - axis, i.e. along the horizontal line of the graph. The dependent variables are written along the Y - axis, i.e. along the vertical line of the graph. Once this has been done, one should determine an interval scale for each axis that is suitable for the data to be graphed. After that, in a bar graph one plots the bars on a graph whilst in a line graph one plots data pairs as data points on a graph and draw a best-fit line which can be either a straight line or a smooth curve.

- **Pie diagram**

According to Liebenberg (1986: 160) a pie diagram in geography is also used to:

- *compare the subdivision of the same geographical variable with one another, and to*
- *compare a geographical phenomenon occurring at different places.*

A pie graph is used to show a proportion of a whole. For instance, Table 2.3 shows an estimation of South Africa's mineral production in 2001.

Table 2.3 South Africa's Mineral Production in 2001

Minerals	Gold	Platinum	Diamond	Copper
Quantity in Kilograms in millions	958	1 849	678	246

Using the information in this table, a pie diagram can be represented as follows:

Figure 2.19 Pie Diagram: South Africa's Mineral Production in 2001

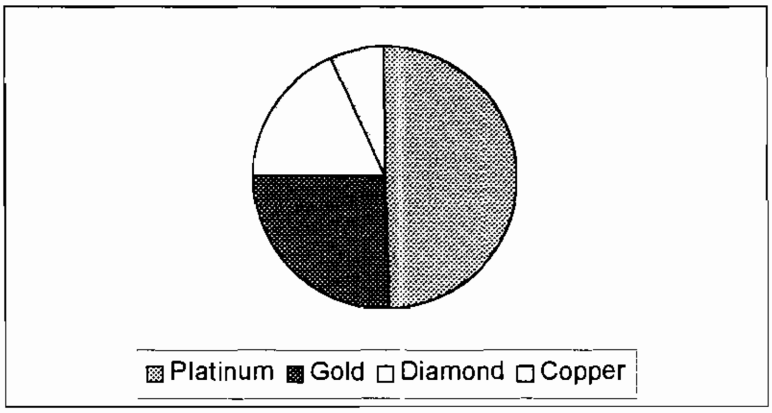


Figure 2.19 compares the subdivisions of mineral production in South Africa in 2001. It is apparent that the production of platinum was the highest, hence it is represented by the largest sector. Copper has the smallest sector of the circle as its production was the lowest.

Learners should be taught how to construct a pie diagram in Figure 2.19 using the following step-by-step approach.

- Step 1

Learners should calculate the total that is to be represented by each circle. The size of the circle equals 360°

- Step 2

Learners should calculate the sizes of the different sectors of the circle using the following equation:

$$\text{Size of sectors in degrees} = \frac{\text{Quantity of a mineral} \times 360°}{\text{Total quantity of all mineral produced in South Africa in 2001}}$$

The size of the sector representing platinum would be as follows:

$$= \frac{1\,849 \times 360°}{3\,731}$$

$$= 178.4$$

$$= 178°$$

Learners should show the calculations for all months.

- Step 3

Learners should add the various answers. The total should add up to **360°**. If it does not add to **360°**, there could be a calculation error and the learners should check each calculation on its own.

- Step 4

Learners should draw a circle of any convenient size. Subdivide the circle using a protractor and a ruler starting at the 12 o'clock position and marking off the sectors in a clockwise direction.

- Step 5

Learners should shade the respective circles' sectors in different colours or colour patterns so that they should be easily distinguishable.

- Step 6

Learners should write down key and legends

- Step 7

Lastly, the circle should be supplied with an appropriate heading.

The educative value of plotting these graphs is that graphing makes it possible for learners to convert measurement into a diagram to show the relationship between the measurements (Martin et al. 1994: 15). Hence they might be able to read and interpret the trends or patterns depicted in the graphs. An interpretation of trends or patterns could influence learners to describe the relationship between the variables on graphs.

2.5.2.4 Describing Relationships between Variables

Once a graph has been constructed, one may realize that the graph is a coded message which needs to be interpreted. The description should give a summary of the relationship between the manipulated and the responding variables. Using Figures 2.17, 2.18 and 2.19, the learner should indeed be able to interpret the trends and patterns revealed by the graphs. By merely glancing at Figure 2.17, it is immediately apparent that July is the month with the highest mean rainfall (94,8 mm) and December the month recording the lowest mean (10,2 mm). It is clear too that Cape Town has a Mediterranean climate because most of the rain falls in winter. From the overall trend of the bars from left to right, learners can *infer* on the whole that the amount of rainfall in Cape Town starts to increase from March to July. Investigators describe the relationship between variables when processing data as they may acquire different kinds of information on the subjects of their research (Fraenkel and Wallen 1996: 115). Hence, the following section discusses the skill of acquiring and processing data.

2.5.2.5 Acquiring and Processing Data

Investigation requires researchers to observe, to collect and analyse data, and to draw conclusions in order to solve a problem (Martin et al. 1994: 15). Consequently, an investigator should be able to conduct an investigation and compile a table related to the data. If an investigation involves the measurements of mass, length, temperature, force and volume, the researcher should be able to construct a table of data using the measuring units of these elements.

After acquiring and processing data the investigator should be able to use the table of data to construct any kind of graph or diagram (cf. 2.5.2.3). The graph should consist of a title which conveys the purpose of the graph (Rezba et al. 1995: 195). This should also be accompanied by a statement of the relationship between the manipulated and the responding variables. Data processing is related to the skill of analysing investigations.

2.5.2.6 Analysing Investigations

Before one conducts an investigation one should determine the variables under study (Fraenkel and Wallen 1996: 48). One should then formulate the hypotheses being tested (Gay and Airaisian 2000: 71). The investigator could also use a supplied description of an investigation to identify the hypotheses being tested (Rezba et al. 1995: 205).

Analysing investigations enables the investigator to identify the manipulated and responding variables (Gay and Airasian 2000: 151; Fraenkel and Wallen 1996: 54; and McMillan and Schumacher 1997: 88). The manipulated variable should be the only variable affecting the responding variable. If there is a constant factor that may affect the investigation, it should be kept from doing so (Rezba et al. 1995: 206).

Analysing investigations also enables the investigator to test, accept or reject and revise hypotheses (Gay and Airasian 2000: 77; Fraenkel and Wallen 1996: 212 and McMillan and Schumacher 1997: 358). If the hypotheses are accepted, the investigator may move to the next problem (cf. Figure 2.7). A revision of the hypotheses may compel the investigator to redefine the problem and gather new data that are needed to test the constructed hypotheses.

2.5.2.7 Constructing Hypotheses

An inquiry involves an investigation of a question, a problem or an issue (cf. 2.3). This entails that the investigator should strive to obtain a solution to the problem. Finding a solution to the problem involves decision making (Lambert and Balderstone 2000:74). Before an inquiry is conducted, the investigator should suggest tentative answers to the problem. These tentative solutions are hypotheses (Gay and Airasian 2000: 71; Fraenkel and Wallen 1996: 56; and McMillan and Schumacher 1997: 95). Hypotheses are predictions about the relationships between variables (Rezba et al. 1995: 219). They guide the researcher on what data to gather (cf. 1.3.4). Sometimes a problem is provided and the researcher is expected to find a solution to it. The researcher may also identify a problem and make predictions about the relationship between variables. Rezba et al (1995: 222) maintain that "... *prediction can be based on fact, opinion, hunch, or whatever resources one may possess.*" Martin et al. (1994: 15) also claim that forming hypothesis is similar to prediction although hypothesising is more controlled and formal.

Subsequently, it is imperative to formulate a testable hypothesis which guides the way the investigation should be designed and take place. The gathered information should be used to make a best educated guess about the expected outcome of the investigation (Martin et al. 1994: 15). Gay and Airasian (2000: 73) have identified four types of hypotheses, namely, inductive, deductive, declarative and null hypotheses.

An inductive hypothesis is a generalization based on observed relationships (Gay and Airasian 2000: 73). For instance, a geographer may generalise that in Southern Africa, rainfall increases from west to east. This observation could become the basis for an inductive hypothesis as the geographer observes that the western side of the subcontinent (Northern

Cape) is dry and has sparse vegetation whilst the eastern part of the subcontinent (Kwazulu Natal) is wet in summer and has dense vegetation.

Deductive hypotheses are generally derived from theory (Gay and Airasian 2000: 73). For instance, the bid - rent theory (land value model) which states that the most expensive or prime sites in the cities are in the Central Business District (CBD). Hence a geographer may hypothesise that departmental stores would be found in the CBD because they are able to conduct their business in a relatively small amount of ground space and build skyscrapers.

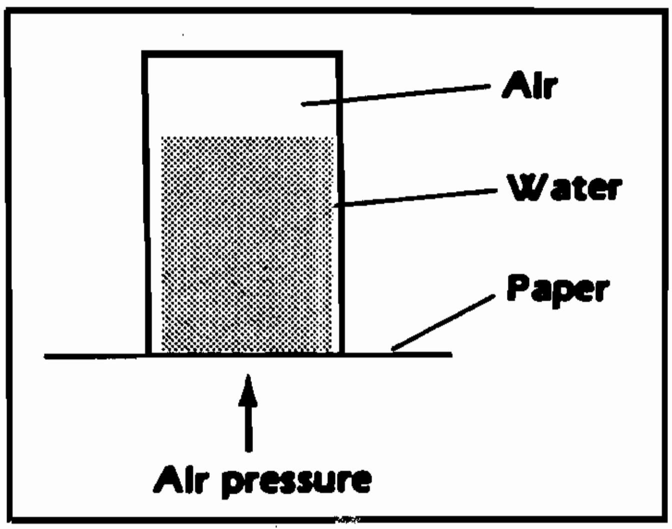
A research hypothesis states an expected relationship or difference between two variables (Gay and Airasian 2000: 74). For example, as air pressure decreases, the ability of the atmosphere to hold heat also decreases. Hence a researcher may verify this hypothesis in a research study or experiment.

The null hypothesis is the hypothesis of choice when there is limited research or theoretical support for a hypothesis (Gay and Airasian 2000: 74). For example, the polar front jet stream varies between latitudes 40° and 60° in the Southern Hemisphere. Jet streams are extremely fast-moving air which can exceed speeds of 230 km per hour. Hence there could be little research or theoretical support for this hypothesis. Constructing hypotheses is a skill which can be applied to the geography curriculum (cf. 4.5.2). The construction of a hypothesis is influenced by the variables of the research problem.

2.5.2.8 Defining Variables Operationally

A definition that attributes meaning to a concept by specifying the procedures that must be conducted in order to measure or manipulate the concept is an operational definition (Ary, Jacobs and Razavieh 1990: 29; Borg and Gall 1989: 26 and McMillan and Schumacher 1997:89). Variables can be defined operationally by applying some kind of a measurement (*a measured operational definition*) or by listing the steps taken in an experiment to produce research conditions (*an experimental operational definition*) (Ary et al 1990: 35). Figure 2.10 illustrates an experiment which can be used to develop the skill of defining variables operationally.

Figure 2.20 Air Pressure



(Friedl 1991: 130)

Using Figure 2.20, the concept air pressure could be defined operationally. For instance, by filling a tumbler with weightless water, covering it with a sheet of paper, and turning it upside down, learners may expect the water to pour out. Asking the learners why the water does not spill out may enable them to realize that it does not spill because air pressure pushes against the paper. Hence learners could define air pressure as the weight of air that exerts pressure.

Operational definition is essential to research because data is collected in terms of observable events and characteristics. The outcomes of operational definitions are that investigators are likely to *observe* and *measure* abstract concepts. to carry out research and gather data relevant to the concepts and to take steps to produce certain experimental conditions (Ary et al. 1990: 29-30).

In the air pressure activity highlighted above, learners' investigations may include the science process skills such as *observing* that the sheet of paper and water do not fall, *experimenting* with tumblers containing different amounts of water and discovering that they all work, and forming a theory about the force that holds the water in the tumbler (Friedl 1991: 130). All these could happen after this investigation has been designed.

2.5.2.9 Designing Investigations

After constructing hypotheses, the investigator designs an investigation to test the hypotheses. The designed investigation should be simple to enable the researcher to collect usable data. The collected data should be able to either support or reject the formulated hypotheses. Rezba et al. (1995: 245) point out that the design of an investigation should include:

- *a description of how the manipulated variable is operationally defined;*
- *a description of how the responding variable is operationally defined;*
- *a description of what factors are kept constant; and*
- *the values of the manipulated variable selected for the investigation.*

An investigator is able to proceed with investigations after they have complied with these processes, which should enable him/her to produce certain experimental conditions.

2.5.2.10 Experimenting

An opportunity to practice all the science process skills which have been discussed, is provided by experimenting. Experiments are a way of learning something by varying some conditions and observing the effect on something else (McMillan and Schumacher 1997: 313). An experiment is a scientific investigation in which the researcher controls some independent variables and observes the effects of these manipulations on the dependent variables (Ary et al. 1990: 298).

The investigator starts with a question which needs to be solved. The first step to find solutions to the problem will be to identify the variables, to formulate the hypotheses, to identify the factors that should be held constant, to define variables operationally, to design an investigation, to rerun trials, to collect data and then interpreting data (Ary et al. 1990: 298; McMillan and Schumacher 1997: 315; and Rezba et al .1995: 251). All these activities include all science process skills that have been discussed in this chapter.

Researchers are expected to employ these science process skills (cf. 2.5.1) as they plan and conduct investigations. After the investigation has been concluded, the investigator writes a report which Rezba et al. (1995: 252) maintain should include:

- *the statement of the question or problem investigated*;
- *the statement of the hypothesis tested;*
- a *written description of the design of the investigation used to test the hypothesis;*
- *a report of the data in a table form* ;
- a *graph of the data;*
- *a statement of the relationship observed between variables*; and

- *a comparison of the findings with an initial hypothesis to see the hypothesis is accepted or rejected by the investigation.*

Experimenting involves verifying a hypothesis through the application of all science process skills. These processes are useful and should be applied when a problem or an issue is investigated. However, researchers such as Jenkins (1989a: 21); Millar and Driver (1987: 51-52); and Millar (1989 47-60) criticise the application of science process skills to the curriculum.

2.6 CRITIQUE OF SCIENCE PROCESS SKILLS

Millar (1989: 47-49) questions if it is possible to teach according to the scientific method because general cognitive processes are not transferrable. It is difficult to prove if skills such as observing, classifying and hypothesising can be taught and transferred to a new situation different from the original one (Millar 1991: 51). Process skills of science are possible to transfer only horizontally, i.e. process skills are transferrable to a situation similar to the original one. This happens because when transferring process skills, learners use reasoning by analogy rather than the application of general rules of procedure to understand (Millar and Driver 1987: 51-52).

Millar (1991: 51) further claims that only a practical technique such as measuring and inquiry tactics such as drawing graphs and identifying variables can be taught and improved. The researcher holds the view that learners can be taught to observe, classify and hypothesise scientifically. For instance, learners are taught to make qualitative and quantitative observations, i.e. they are taught to carefully explore all properties of an object. This may include properties such as weight, volume, temperature, colour, odour, shape and texture. Hence the researcher concludes that it is possible to teach and develop the application of science process skills in problem-solving, if learners are afforded opportunities to always engage science process skills in whatever learning activities they do.

Jenkins (1989: 33) also regards the process-led approach as flawed because some skills such as accuracy, neatness and observing do not transfer. Jenkins (1989) cited by Wellington 1989: 9) further argues that scientific knowledge can become appealing and accessible if it is taught in an exciting and interesting context. Millar (1989: 52-56) criticises the idea that learners can be taught to observe, classify, infer and hypothesise, because these skills are present in infants since birth. Children can observe, classify, infer and hypothesise without being taught. They are able to observe and classify different faces and identify their mothers.

It is further argued that these skills cannot be practised in isolation of knowledge or experience. People use their knowledge and experiences whenever they observe, classify, infer and hypothesise. Knowledge gives meaning and value to science process skills as general intellectual skills are applied during the life-cycle of a person (Millar and Driver 1987: 42) as formal instruction implies progress and development.

Millar and Driver (1987: 42) also claim that proponents of science process skills do not have any idea of how to teach these skills because what constitutes the growth or progression in science process skills is not known. This argument is flawed because not all science process skills can be practised without receiving formal instructions. It is not that simple for a person to draw tables and graphs, recognize variables, interpret data or define operationally without learning how to perform these skills. Progress or growth in process skills of science is visible when people apply all the science process skills they have learnt. If investigators, when answering questions, identify variables, formulate hypotheses, identify factors to be held constant, define variables operationally, and collect and interpret data, it shows that they are capable of planning and conducting investigations on their own. This proves maturity and growth in conducting scientific investigation that is supported by evidence. Hence, the researcher argues that it is possible for geography teachers to develop their learners' growth and progress in science process skills (cf. Chapter 4).

2.7 CONCLUSION

Examples given in this chapter indicate that science process skills are applicable to the teaching of geography. This is also supported by the fact that there are many geographical questions which need to be tackled and solved. The International Charter on Geographical Education (1992: 5) maintains that geographers asks the following questions:

- *Where is it?*
- *What is it like?*
- *Why is it there?*
- *How did it happen?*
- *What impacts does it have?*
- *How should it be managed for the mutual benefit of humanity and the environment?*

Finding solutions to these problems requires investigating the location, situation, interaction, spatial distribution and differentiation of phenomena on earth. Consequently, geographers are required to possess skills in:

- *using verbal, quantitative and symbolic data such as text, pictures, graphs, tables, diagrams and maps;*
- *practising such methods as field observation and mapping, interviewing people, interpreting secondary resources and applying statistics; and*

- *using communication, thinking, practical and social skills to explore geographical topics on a range of scale from local to international. Such a process of inquiry will encourage students to identify questions and issues; to collect and structure information; to process, interpret and evaluate data; to develop generalisations; to make judgements and decisions; to solve problems; to work cooperatively in team situations; and to behave consistently with declared attitudes* (Smit and van der Merwe 1992/1993: 149).

The Guideline Document and Interim Syllabus for Geography Grades 10 to 12 (1996: 4) encourages learners to develop skills listed above. Almost all secondary school geography textbooks used in South Africa have chapters on science process skill activities (Hurry, Hart and De Montille 1991: 322-333; Ranby 1994: 52-78; Swanevelder, Van Huyssteen and Kotze 1987: 3-49; Swanevelder, Kotze and Roos 1986: 3-40; Swanevelder, Van Kradenburg and Hatting 1985a: 3-28; Swanevelder, Kotze and Myburgh 1985b: 1-21 and Swanevelder, Kotze and Van Kradenburg 1985c: 1-21). Contents and activities in the cited sources require learners to possess scientific skills of analysis. It is imperative for geography teachers to encourage learners' development in these skills. In this way, geography education may contribute towards the development of outcomes-based education principles of developing people who can communicate, solve problems, are confident, can work with others, possess life skills and take part in economic and social life with confidence.

Furthermore, geography learners are expected to acquire and possess skills in advanced analysis of photographs and maps, fieldwork and statistical techniques. Swanevelder et al. (1987: 3-48) maintain that advanced analysis of photographs and maps should include the following:

- *Advanced interpretation of a section of an oblique aerial photograph (Calculating the scale: Why? What? How? - Identifying geographical phenomena - Formulating the problem and the hypothesis and applying scientific method to interpreting oblique aerial photographs);*

- *Advanced interpretation of a stereopair of vertical aerial photographs (Advanced interpretation of vertical aerial photographs by means of stereoscopic vision - Problem solving in geography: applying a more detailed procedure of analysis);*

- *Advanced interpretation of a 1 : 50 000 topographical sheet (Identifying and interpreting physical features and cultural features);*

- *Advanced interpretation through the integrated use of photographs and maps (Formulating the hypothesis, i.e. statement of probability; analytical techniques. i.e. observations, collection of data, analysis and interpretation of the physical environment);*

- *Fieldwork in an urban area; and*

- *Techniques of collecting and processing data: the statistical method (Problem and hypothesis formulation: obtaining quantitative data, tabulating data, sampling and testing the hypothesis).*

All the listed skills involve the application of both basic and integrated science process skills to the teaching of geography. It is the researcher's assumption that the teaching and learning of geography cannot happen without applying some science process skills in one way or the other. The next chapter discusses the nature and structure of geography education and their relations to outcomes-based education.