CHAPTER FOUR

THE APPLICATION OF SCIENCE PROCESS SKILLS TO THE TEACHING AND LEARNING OF GEOGRAPHY

4.1 INTRODUCTION

Chapter three has highlighted the nature and structure of geography. It also discussed the implications of the structure of geography on the application of outcomes-based education to the teaching of geography. This chapter attempts to explain how geography teacher consideration of Piaget's theory of intellectual development can contribute to the development of the critical and developmental outcomes and science process skills in geography classrooms. The relationship between the development of cognitive functioning and the development of science process skills in learners receives attention. The chapter also reviews how geography teachers can develop science process skills in their learners through geographical activities. It seems as if there is no research in South Africa on the application of science process skills to the teaching of geography (Appendix 5). This chapter also attempts to address this situation.

It is assumed that geography lessons in most schools in South Africa will in future take place in geography rooms, where teachers and learners will be able to carry out practical investigations and demonstrations (cf. 7.2.3). Thus, the emphasis of this chapter is on learner activities which promote the acquiring and mastering of the science process skills. It is hard to imagine the study of geography without a strong emphasis on the development of process skills. Geography is a practical subject, which requires teachers to promote tasks that develop the application of science process skills. These skills are likely to enhance the discovery and learning of new geographical knowledge.

The researcher also assumes that the application of science process skills could develop learner competence in procedures of scientific inquiry. It is likely to empower learners to have an opportunity to 'feel' for geographical phenomena, to develop practical skills and techniques and to tackle open-ended tasks as problem-solving scientists. Lastly, the chapter also attempts to highlight how basic science process skills could be developed through mapwork activities. Mapwork is an essential part of the secondary school geography curriculum in South Africa. It is also important note that this is just an example of how mapwork activities can promote the learning of basic science process skills. It does not imply that mapwork is the only section of the geography syllabus that can be used to develop the learning of basic science process skills.

4.2 THE NEED TO APPLY SCIENCE PROCESS SKILLS TO THE TEACHING OF GEOGRAPHY

Van Aswegen et al. (1993: 18) have discussed the implications of the process approach for the teaching of biology which is also applicable to the teaching of geography. The advantages are listed as follows:

- learners become critical thinkers and are actively involved in seeking information that can be used to solve a problem or answer their questions;

- a process approach gives more meaning to the learning activities because learners see processes as a vital part of what they do in the geography class; and

- geography becomes an experience learners enjoy, with the result that they are motivated to greater achievement.

It is also assumed that teachers' consideration of Piaget's theory of cognitive development is likely to enhance the development of science process skills in learners, which suggests that there is a relationship between Piaget's stages of development and the acquisition and performance of science process skills.

4.3 PIAGET'S THEORY OF LEARNING AND SCIENCE PROCESS SKILLS

Kagan (1980) cited by Wolfinger (1984: 40) indicates that Jean Piaget's theory of intellectual development is based on the following three assumptions:

- the main source of a child's knowledge is an activity. By engaging in activities, a child is likely to learn something and to gain knowledge about that activity;

- the major function of knowledge is adaptation. This means that a child who has acquired knowledge through an activity should be capable of adapting and using the knowledge in different contexts; and

- the structures that are created through the action of a child form an uninterrupted and invariable cycle. This assumption forms the basis for Piaget's four developmental stages.

These four developmental stages occur gradually, and continuously in an invariant sequence from birth through adulthood. In these stages of development, children also show a gradual development of mental processes. Piaget's four stages of development are:

- the sensorimotor stage which starts at birth to eighteen months;
- the preoperational stage which begins at eighteen months through six and one-half years;
- the concrete operational stage which begins at six and one-half years through eleven or twelve years; and
- the formal operational stage which onsets at eleven years through to adulthood.

Sections 4.3.1 to 4.3.5 discuss Piaget's stages of cognitive development and their implications for the teaching and learning of geography. The following paragraphs discuss the sensorimotor stage.

4.3.1 The Sensorimotor Stage

Children in this stage of development are at a preverbal stage as they cannot speak. This is a reflex stage in which children express their thoughts through actions and not words (Piaget 1952: 25-29; Piaget 1964: 9; and Piaget and Inhelder 1969: 3-4). Furthermore, Piaget (1980: 11); Piaget (1981: 14); and Piaget and Inhelder (1969: 4) refer to this stage as the stage of practical and sensorimotor intelligence which includes reflexes and instinct present at birth.

Children learn and understand their world through physically manipulating the objects around them. For example, to grasp a stick in order to pick up a remote object is an act of intelligence. McCown, Driscoll and Roop (1996: 36) and Slavin (1997: 34) point out that infants learn and interact with their environment by using their senses and motor skills. Children who are in this stage may cry whenever they need attention or when they are hungry.

Wolfinger (1984: 41) maintains that children use their reflexes and are engaged mainly in tasks that need physical movement or jumping such as building blocks until the entire structure topples over. Hence, these activities are psychomotor in nature. Children learn first through accidental learning and then through more intentional trial-and-error learning (Slavin 1997: 34). One of the benchmarks of the sensorimotor stage is imitation (Piaget and Inhelder 1969: 53-56; Piaget 1981: 40 and McCown et al. 1996: 36). Imitation is a systematic effort to copy new gestures from a model (Piaget 1981: 40 - 41; Piaget and Inhelder 1969: 53) and it is believed to be the ability of the child to copy behaviours and sounds. The child starts to copy behaviours and sounds that are part of his or her everyday observation. For example, if the mother always smiles at her baby, the child is likely to smile back whenever the mother plays with him /her. Piaget (1929: 153) calls this act involuntary imitation, i.e. the child smiles without seeing any difference between his/her mother's smile that it is independent of him/her and the sound (s)he has produced. Sometimes, imitation may start after the disappearance of the model, i.e. the child may continue to repeat a gesture after someone has stopped the gesture. Piaget and Inhelder (1969: 53) call this type of action deferred imitation which constitutes the beginning of representation of action.

Children who are less than eighteen months old have no sense of object permanence (Esler and Esler 1981: 22, McCown et al. 1996: 36 and Wolfinger 1984: 41). They think that a concept or object that is not in the immediate environment does not exist. However, when children reach the age of eighteen months, they start to realize that concepts, objects or people that they cannot see, do not disappear, but still exist somewhere (Piaget and Inhelder 1969: 14, and Esler and Esler 1981: 22). Object permanence enhances advanced thinking because once children realize that objects exist even when they are out of sight, children are able to use symbols to represent the absent objects in their minds (Piaget 1964: 13 and Slavin 1997: 34). For instance, a child can imagine what his/her toy or milk bottle looks like even when it is out of sight.

It is important to note that in this period, children are able to *observe* and recognize their mothers or other family members. This act relates to the basic science process skill of *observing* where they are also able to distinguish their mothers' voices or faces from the voices or faces of other people, it relates to the skill of *classifying*. Children in this stage are able to perceive objects in terms of relations of similarities and dissimilarities (Inhelder and Piaget 1958: 5). This process relates to the basic science process skill of *classifying*. The end of this stage culminates at about two years of age or when the child starts to speak. The preoperational stage is reached at this point of onset of language (Wolfinger 1984: 42). By the end of the sensorimotor stage, children have progressed from the trial-and-error approach to problem solving to a more planned approach (Slavin 1997: 34). For example, if a child needs to play with a toy which is on top of a cupboard, (s)he will think about the problem of reaching the toy. Then, (s)he will figure out possible solutions to the problem. (S)he may drag a chair to the cupboard, climb the chair and reach out for the toy. This process indicates that the child has sought to solve the problem by following a planned approach until (s)he could reach the top of the drawer and retrieve the toy.

The process mentioned above is an intellectual process because the child uses his/her intelligence to get hold of the toy. Hence, the whole act links very well with the critical outcome of *identifying and solving problems by using creative and critical thinking* (cf. 3.8). Furthermore, the act of using the chair to reach the toy also demonstrates the critical outcome of *understanding that the world is a set of related systems, i.e. problem-solving contexts do not exist in isolation*.

4.3.2 The Preoperational Stage

The preoperational stage is the stage at which children learn to represent things mentally (Slavin 1997: 35). This stage has two substages, namely, the preconceptual stage and the intuitive stage (Wolfinger 1984: 41). The preconceptual stage lasts from the beginning of language until about four and one-half years of age. At this substage, children are also able to think and speak. However, their thinking process is restricted by perceptual limitations as children can focus only on one dimension of an object at a time (Piaget 1964: 17-18 and Esler and Esler 1981: 22). This implies that the child's thought does not get reversible (cf. 4.3.2.4).

A preoperational child lacks conservation skills (Donald, Lazarus and Lolwana 1997: 46; Esler and Esler 1981: 22; and Slavin 1997: 35). Conservation (cf. 4.3.2.2) is the ability to understand the concept that certain properties of an object (such as weight) remain the same despite changes in other properties (such as length) (Piaget and Inhelder 1969: 98; and Slavin 1997: 35). This limitation prevents the child from understanding transitions in shape, size, time and number.

In the intuitive substage, the child may experience a transitional stage in which (s)he gives a correct answer to a conservation task without providing a reason (Esler and Esler 1981: 22). For instance, if an equal amount of water is poured into two glasses of the same volume but different heights, the child would be able to infer that the glasses have an equal amount of water without providing their volumes as a reason. This example shows that a child who is at this substage, can perform the basic science process skill of *inferring* without providing adequate reasons for his/her inference.

The thinking processes of preoperational children differ from those of the adult in six crucial ways, namely, egocentrism, conservation, reversibility, centring, transduction and concreteness (Wolfinger 1984: 43). Mwamwenda (1995: 92) and Piaget 1929: 194, 203 and 279) discuss animism as another major characteristic of the preoperational stage. In the next paragraph each of these characteristics and their association with science process skills and critical outcomes are briefly discussed.

4.3.2.1 Egocentrism

Mwamwenda (1995: 93); Piaget (1964: 14) and Wolfinger (1984: 42) maintain that a child is egocentric as (s)he sees everything as revolving around himself/herself. It is difficult for a child to appreciate another person's point of view if it does not agree with his/her own thinking. Egocentric children use words whose referent is mostly clear only to them. For instance, the child may say, "*she climbed it with me*". In this statement, it is impossible for the listener to understand what is meant by such a statement.

The child is only able to consider other people's point of view through repeated interaction with people who have different views with his/hers (Mwamwenda 1995: 93 and Wolfinger 1984: 42). Repeated social interaction should be encouraged because it decreases egocentrism and relates well with the critical outcome of *working effectively with others in a team, group, organisation and community.* The child realizes that his/her views can be questioned and challenged (Mwamwenda 1995: 93). From the age of four, children find that their judgements are contracted by others (Inhelder, Sinclair and Bovet 1974: 20). Children gradually start to understand that other people do not have the same knowledge or idea that they have. It is interesting to note that they begin to understand that their mothers are not there to cater only for their needs.

At this stage a kindergarten teacher can start to introduce basic science process skills' activities such as *observing, communicating* and *classifying*. Children use their senses to *observe* objects and events. They also look for patterns in their observations (*classification*). The questioning and challenging of other children's ideas is likely to encourage children to form new concepts by searching for similarities and differences which relates to the basic science process skill of *classification.* The process of questioning and challenging other children's ideas also implies that children are likely to *communicate* orally what they know or are able to do. This process of social interaction could be linked to the critical outcomes of *working effectively with others*, and demonstrating the ability to *communicate effectively using language skill in the modes of oral presentation*. As Mwamwenda (1995: 93) has suggested, group discussions and activities play essential roles in helping children to become less egocentric.

4.3.2.2 Conservation

Conservation is the ability of an individual to realize and understand that a change in the form of an object does not necessarily change the quantity of that object (Piaget and Inhelder 1969: 98). A preoperational child is a nonconserver as (s)he cannot do the majority of the conservation tasks correctly. The main reason for the child's inability to conserve is his/her inability to *coordinate variables* (Wolfinger 1984: 42) which implies that a preoperational child is unable to perform integrated science process skills such as *describing the relationship between variables*.

Preoperational children tend to concentrate on the given condition, not taking into consideration what has already taken place or considering previous experience (Mwamwenda 1995: 94). Subsequently, preoperational children have difficulty with *inferring* some explanations or *predicting* possible outcomes before they are actually *observed*.

Mwamwenda (1995: 94) also points out that some preoperational children experience difficulties with *classification* activities as they concentrate on one member of the class at a time, paying little attention to other members of the class. These children are unable to grasp the similarity between the members which constitute the definition of a superordinate or universal class (cf. 4.3.3.3). This implies that the intellect of these children has not fully developed yet as overt *classification* is beyond their reasoning.

4.3.2.3 Centring

Centring is the process whereby a preoperational child focuses on one property or dimension at the expense of others (Dembo 1991: 53 and Wolfinger 1984: 43). The child pays attention to only one aspect of an object or situation at a time (Slavin 1997: 36). This tendency makes the child incapable of shifting his or her attention from one attribute to another while retaining the memory and use of the first characteristic (Wolfinger 1984: 43), thus failing to decentre (Mwamwenda 1995: 94). Decentralisation permits the mastery of the present situation by connecting it to former situations and by anticipating future ones (Piaget 1981: 63). This implies that it could be difficult for a child who cannot decentre to *predict* future outcomes. Distorted reasoning is the reason why the child fails to answer conservation questions. Mwamwenda, Dash and Das (1984) cited by Mwamwenda (1995: 94) argue that the child is unable to take other features of an object which might counteract or compensate the twisting and distorting effects of his/her tendency to centre on a single dimension into account.

For instance, a child observes two small glasses of the same size and shape which contain equal amount of water. The water from one of the glasses is poured into a third glass, which is taller and narrower. The preoperational child is likely to conclude that the third glass contains more water than the other glass because it is "taller". The child therefore, recognizes qualitative identity, but rejects conservation of quantity (Piaget 1972: 6). In this example, the child focuses on one dimension (length) and forgets about the other dimension (width). Therefore, the child bases his/her assertion on the static perceptual configuration, i.e. (s)he has perceived each state of the system individually instead of envisaging the situation in terms of reversible transformation which leaves the quantity constant (Inhelder and Piaget 1958: 247).

4.3.2.4 Reversibility

Reversibility is "*the ability to return to the point of origin, to do and undo, to go in one direction and compensate for it in another direction*" (Dembo 1991: 51). Reversibility of thought allows an individual to start at point A, move through the thought processes to point B, and then back to point A (Piaget and Inhelder 1969: 20; and Wolfinger 1984: 43). This is the ability of the child to change his/her thinking in order to return to the starting point (Slavin 1997: 36). The preoperational child is incapable of reversible thinking (Inhelder and Piaget 1958: 247).

For example, every mathematical or logical operation is reversible. Adults are likely to know that 3 x 3 = 9, then 9 ÷ 3 = 3 but a preoperational child may not be able to solve the division problem of 9 divided by 3.

4.3.2.5 Transductive Reasoning

A preoperational child does not think inductively and deductively like adults do. Inductive reasoning begins from the specifics and moves to the general (cf. 2.3.1) whilst deductive reasoning starts from the general to the specifics (cf. 2.3.2). The preoperational child thinks from specific to specific without touching on the general (Dembo 1991: 54). For instance, the child may conclude that every object that (s)he can take to his/her mouth is edible without considering that not all objects are edible.

Transduction is characterised by syncretisms or the linking together of unrelated things and juxtaposition which is the giving of successive unrelated judgements (Piaget 1929: 181 and Wolfinger 1984: 43). A child who is employing syncretic reasoning, places together objects which do not belong to the same class (Mwamwenda 1995: 94). As such, the child's skill of *classification* is illogical. The child is also likely to change the criterion for *classification* from time to time. For instance, a child may *classify* stones first on the basis of their colour and then *classify* the same stones on the basis of their shape.

4.3.2.6 Concreteness

Wolfinger (1984:43) observes that adults think in terms of words and symbols. Preoperational thought processes also differ from adult thought as a result of the child's requirement of concreteness or reality which implies that preoperational children are unable to learn concepts through the use of words instead of objects. Preoperational children develop new concepts through the use of real objects instead of the use of words. For example, adults can read about dew point temperature as the point at which condensation takes place. Children may learn the same concept, i.e. dew point temperature by placing ice cubes into a container of cold water and *observe* the point at which dew is formed outside of the glass by inserting a thermometer in the container. It is important to note that the teacher should demonstrate this activity for children to *observe* and understand the abstract concept 'dew point temperature'. This example indicates that children in this stage are able to be engaged in integrated science process skill such as *experimenting* which means that the use of a thermometer can also be linked to the critical outcome of *using science and technology effectively and critically*.

4.3.2.7 Animism

Animism describes the tendency to regard objects as living and endowed with will (Piaget 1929: 194). Piaget's (1951) cited by Mwamwenda (1995: 92) mentions that a preoperational child is unable to differentiate between living and non-living things, assuming that animals can talk like people, that rocks have life and that trees are capable of thinking. If a child sees a stone and a feather thrown upwards and the stone falls to the ground, whilst the feather floats in the air, the child may say this is because the stone wants to fall to the ground, whilst the feather prefers to float. This also confirms that children at this stage cannot give meaning to what they *observe*, i.e. they cannot make sense of things which implies that they fail to *infer*. They fail to *infer* that the stone falls to the ground because it is heavy and the feather floats in the air because it is light in weight.

Animism is promoted by children's story books where animals are depicted as capable of talking (Mwamwenda 1995: 92). Adults also tell stories that portray animals as being able to speak, an act which does not happen in reality. The same perception is also portrayed by television cartoons that show animals talking to one another.

4.3.3 The Concrete Operational Stage

The concrete operational stage starts from about seven years and lasts until approximately eleven to twelve years of age and it is marked by the acquisition of elementary operations of classes and relations (Piaget 1981 14). Furthermore, Piaget (1964: 47) and Slavin (1997: 38) note that this is a stage at which children develop skills of rational reasoning and conservation, however, children can use these skills only when dealing with familiar situations. Wolfinger (1984: 44) has identified four characteristics of this period, namely:

- *the appearance of operations.* For instance, a child in this stage may be able to do the calculation one plus one equals to two;
- *an inability to use verbal reasoning;*
- a *decrease in egocentricity* (cf. 4.3.2.1); and
- *the appearance of reversibility* (cf. 4.3.2.4).

Esler and Esler (1981: 25) and Seifert (1983) cited by Mwamwenda (1995: 95) point out that this period is known as the concrete operational stage because the child can use logical processes of reasoning on the basis of concrete evidence. For instance, (s)he may be able to deduce that water used to wash clothes is undrinkable because it is dirty or it is foamy (*inference*). This example highlights the consequences of polluted water which is part of the geography curriculum.

Similar to an adult, the child is capable of assessing objects and situations in a realistic manner (Mwamwenda 1995: 95). However, unlike an adult, a concrete operational child has difficulty with abstract thought (Slavin 1997: 38). As a result of logical reasoning, the concrete operational child is likely to be capable of comprehending great number of objects, events, and living things in his/her environment. The child is also likely to impose some kind of order in his/her world by observing similarities, differences, and interrelationships between objects which implies that the child is capable of *classifying* objects and events on the basis of their *observable* characteristics (Inhelder and Piaget 1958: 248).

Inhelder and Piaget (1958: 248-249) and Mwamwenda (1995: 95) note that the concrete operational child is capable of exercising logical skills in conservation tasks of quantity, length, area, number, weight and substance. This stage differs from the preoperational stage because the concrete operational child uses the principles of identity, reversibility and compensation which enhance mental development.

The principle of identity (cf. 4.3.2.2) entails that the amount of water stays the same despite any perceptual change, unless some amount is added or taken away. This implies that the child is capable of *identifying and describing variables* that remain constant or that are manipulated.

According to the principle of reversibility (cf. 4.3.2.4), if two identical tall beakers are filled with an equal amount of water and the contents of one beaker are poured into a wide container, a concrete operational child is likely to recognize that the amounts of water in the beaker and the flat container remain the same. If the water is poured back to the beaker, it will contain its original amount. This example is associated with the critical outcome of *collecting, analysing, organising and critically evaluating information*. Furthermore, this process can be linked to the integrated science process skill of *experimenting*.

The principle of compensation (cf. 4.3.2.3) entails that a change in one dimension is balanced by a compensating or reciprocal change in another dimension (Good and Brophy 1995: 39).

For instance, in the example given above, the length of the beaker is compensated by the width of the container, hence the child may be able to identify and describe length and width of the containers as the variables that are likely to affect the perceived amount of water.

Another difference is that the preoperational child responds to perceived appearances, whilst the concrete operational child responds to *inferred* reality which is the meaning of stimuli in the context of relevant information (Slavin 1997: 38). Consider the following example, in cities most workers commute between their homes and places of employment by public transport. If a concrete operational child is asked why workers use public transport, (s)he is likely to *infer* that it is because public transport is cheaper than driving a car, public transport is faster, the use of public transport reduces air and noise pollution or most workers do not have their own motor vehicles. All the mentioned reasons are *inferred* reality as the child *infers* situations which are real.

Slavin (1997: 39) has also noted that concrete operational children can acquire and master abilities such as seriation, transitivity and class inclusion. The following section emphasises how these abilities are associated with science process skills.

4.3.3.1 Seriation

Seriation is the ability to arrange objects in a logical progression from least to most according to size, weight or volume (Good and Brophy 1995: 39; Piaget and Inhelder 1969: 101; and Slavin 1997: 39). It is also the product of a set of asymmetrical transitive relations connected in series (Inhelder and Piaget 1958: 5-6).

Concrete operational children are capable of seriation from the ages of four to seven (Piaget 1972: 8). Such children are capable of ordering and *classifying* things according to some criteria or other dimensions.

For instance, the teacher may ask learners to use information in Table 4.1 on the next page to arrange settlement types from the smallest to the largest in terms of size and complexity. Learners may then use the given squares, dots or open circles to arrange the settlement types. These symbols have not been linked to their descriptions. Then, the learner puts the name of the relevant settlement type next to each symbol.

Instruction: Arrange the following symbols of settlement according to their sizes from the smallest to the biggest.

Table 4.1Types of Settlement

Town, City, Farmstead, Village. Megalopolis, Metropolis, Rural hamlet, Conurbation

Table 4.2 below, links the symbols to their correct descriptions. It shows how the learner is likely to respond to this seriation task by using the criterion of size of the symbols.

Table 4.2 Seriation of Settlements

○	☞	Farmstead
○	☞	Rural hamlet
⊙	☞	Village
◎	☞	Town
⦿	☞	City
◉	☞	Metropolis
▣	☞	Conurbation
	☞	Megalopolis

The purpose of this task in Tables 4.1and 4.2 is to help learners to *classify* the settlements on the basis of size as an *observable* characteristic. This implies that in this task, learners will be involved in the basic science process skills of *observing* and *classifying*. Furthermore, the process of *classifying* may lead to concept formation as learners would be required to link the settlement with its relevant descriptor. Engagement in this task is likely to develop the critical outcome of *communicating effectively using visual, mathematical and language skills*. *Classification* of the settlements on the basis of size as an *observable* characteristic could also develop the critical outcome of *identifying and solving problems by using creative and critical thinking*. Thus mastering of seriation tasks enhances the development of the transitivity skill (Piaget 1972: 8 and Slavin 1997: 39).

4.3.3.2 Transitivity

Transitivity refers to the ability of the child to *infer* a relationship between two objects on the basis of knowledge of their respective relationship with a third object which means that the child can mentally arrange and compare objects.(Piaget 1972: 6 and Slavin 1997: 39). For instance, a teacher informs learners that Johannesburg is larger than Pretoria and Pretoria is larger than Bloemfontein. Only concrete operational children should be able to comprehend logical *inferences* such as these. It may not be that simple for preoperational children to realize that in this statement Johannesburg is larger than Bloemfontein.

Furthermore, a concrete operational child is also likely to comprehend statements such as "*What will happen if...*". For example, if the teacher asks *"What will happen if a large number of people migrate from rural areas to the cities"*. The concrete operational child is likely to explain how rural depopulation will affect both rural areas and the cities. Transitivity can be linked to the integrated science process skill of *constructing hypotheses*. This is also likely to contribute to the critical outcome of *collecting, analysing, organising and critically evaluating* *information*. Sometimes, learners might be required to *conduct investigations* and do research to test their *hypotheses*.

After this process, learners are likely to *communicate* effectively their findings, which *is a critical outcome which involves communicating effectively using visual, mathematical and/or language skills in the modes of oral and/or written presentation*. The whole process may also contribute to the development of the critical outcome of learners *managing themselves and their activities responsibly and effectively*. Learners might be required to conduct the research in the city, in the rural area or in the library, hence they may be required to manage their times and programmes well. Furthermore, the teacher may group learners in pairs to collect data. The grouping of learners might contribute to the development of the critical outcome of learners being able to *work effectively with others* as a *member of a team, group, organisation or community*.

4.3.3.3 Class Inclusion

Class inclusion refers to the ability of the child to think concurrently about a whole class of objects and relationships among its secondary classes (Slavin 1997: 39). The following classroom scenario is used to explain how class inclusion can be taught in the geography classroom. The teacher informs the learners that there are 20 apricots and 10 oranges in the refrigerator and asks the following questions:

Teacher: *"How many apricots are in the refrigerator?"*

Learners: *"Twenty."*

Teacher: *"How many oranges are in the refrigerator?"*

Learners: *"Ten."*

Teacher: *"Are there more apricots than oranges in the refrigerator?"*

Learners: *"More apricots."*

Teacher: *"Which is the most - apricots or fruit?"*

Some learners: *"More apricots."*

Other learners: *"More fruit."*

In this example, fruit is considered as a whole class and the subordinate classes are apricots and oranges. Children who answered that there were more apricots than fruit lacked the ability to think simultaneously about the whole class and the subordinate class. They are thus unable to make comparisons between classes. Hence, it could be difficult for those children to apply some *classification* tasks fully. Children who answered that there were more fruit than apricots, show reversibility of thinking which implies that they are able to recreate a relationship between a part (apricots) and a whole (fruit). This also implies decentred thought because they can focus on two classes simultaneously. These children are at a concrete-operational stage as their thinking is not limited to reasoning about part-to-part relationships but about part-to-whole relationships (Slavin 1997: 39). Hence, these children are likely not to experience major problems with some *classification* tasks.

This example can be related to the critical outcome of developing learners who should be able to *identify and solve problems by using critical and creative thinking skills.* In this example, learners are required to think about the whole class and the subordinate class, hence, learners are required to solve the problem of class inclusion by using critical and creative thinking skills.

4.3.4 Formal Operational Stage

The formal operational stage is the final stage of Piaget's theory. It starts from approximately eleven years of age and continues into and throughout adulthood. Its hallmark is abstract reasoning (Good and Brophy 1995: 40 and McCown et al. 1996: 47) and the ability to think in symbolic terms and comprehend abstract content meaningfully without requiring physical objects or even imagery based on past experience with such objects (Good and Brophy 1995: 40-41). It is characterised by thought employing the logic of propositions freed from the content (Piaget 1981: 14). Learners in this stage can be engaged in basic science process skills such as *communicating* abstract phenomena. They might be able to use conventional signs and other geographical symbols to *communicate* or interpret geographical contents in topographical maps and synoptic weather maps (cf. 2.5.3 and 4.6.1). This process could contribute to the development of the critical outcome of *communicating effectively using visual, mathematical and/or language skills in the modes of oral and/or written presentation*.

McCown et al. (1996: 40) and Slavin (1997: 39) argue that learners who are in this stage are capable of thinking logically about tangibles and they should also be able to deal with possibilities. They can think in terms of a *hypothesis* as they can see beyond the 'here and now'. They are also capable of thinking about '*if - then*' situations (cf. 4.3.3.2) which involve abstract relationships (Donald et al. 1997: 47). For example, learners are able to consider that if '*Coriolis Force is nought at the Equator, then the particles moving in the Equator cannot be deflected either to the right or to the left.*' This example is likely to develop the following integrated science process skills in learners:

- *Identifying variables*: Learners identify variables such as Coriolis force and particles moving in the Equator.

- *Constructing hypotheses*: If Coriolis force is nought at the Equator, then the particles moving in the Equator cannot be deflected either to the right or to the left.

- *Describing relationships between variables*: There is a relationship between Coriolis force and the movement of particles in the Equator. If Coriolis force is nought, then the particles moving in the Equator cannot be deflected either to the right or to the left.

Furthermore, Biehler and Snowman (1993: 66) note that formal operational learners are engaged in mental 'trial and error' in order to *test hypotheses* consciously. Learners, thus are able to examine abstract problems systematically and generalize about the results (Eggen and Kauchak 1997: 43). For example, learners may consider that if Mount Everest is higher than Mount Kilimanjaro, and if Mount Kilimanjaro is higher than Mount Aux Sources, then Mount Everest is higher than Mount Aux Sources. Formal thinkers are able to think abstractly and generalize that, of the three mountain peaks, Mt Everest is the highest.

Biehler and Snowman (1993: 66) also maintain that "*the term 'formal' reflects the ability to respond to the form of a problem rather than its content, and to form hypotheses*". For example, the formal operational thinker can solve the following map scale analogies. Suppose the teacher asks learners to convert the following word scales into ratio scales; which are:

- 1cm = 50 000 cm, and
- 1cm = 0,5 km.

The learner is likely to realize that regardless of the different content, the form of the two problems is the same as both analogies are based on ratios. Thus, the learner may hypothesize that 1 cm on the map represents 50 000 cm or 0,5 km in reality.

Adolescents are also capable of handling problems that involve many factors (Pressley and McCormick 1995: 150) and they are able to *isolate and control variables* in forming conclusions (Eggen and Kauchak 1997: 44). For example, the learners may be asked to explain why the western part of South Africa is dry and sparsely populated. Formal thinking learners may be able to isolate the fundamental influences of this problem and be able to consider *variables* such as the influence of the sea, the central plateau of southern Africa and the location of the subcontinent. Systematic analysis of both *variables* and discarding of those that are not applicable (Mwamwenda 1995: 99) empower the learners to attempt to solve the problem by forming hypotheses, mentally sorting out solutions, and systematically testing the most promising leads (Biehler and Snowman1993: 66). For the learners to be able to perform these tasks, they should be able to perform the integrated science process skill of *describing relationship between variables*.

In view of this, it is not surprising that mastery of formal thought equips learners with powerful intellectual skills. As such, the learners can *infer* "invisible forces" and thus they can solve problems involving such forces. *Inferring* is a basic science process skill which enables people to appreciate their environment and interpret and explain things which happen around them (Rezba et al. 1995: 69). For instance, to explain why the western part of South Africa is dry and sparsely populated, learners may consider the fact that the western part of South Africa is surrounded by the Atlantic ocean which has the cold Benguela current. As the air which blows from the sea to Namaqualand is cold and dry, the area will experience little rainfall and the western part is sparsely populated because arable farming is virtually impossible.

Flavell (1963) cited by Dembo (1991: 56) and Mwamwenda (1995: 98 -100) identified four main types of reasoning that are characteristics of formal operations namely, propositional, proportional, hypothetico-deductive and combinatorial reasoning. These types of reasoning are likely to contribute to the development of the critical outcome of *demonstrating an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation*. The following paragraphs attempt to show how these characteristics are associated with science process skills and the critical outcomes.

4.3.4.1 Propositional Reasoning

Mwamwenda (1995: 98) regards a proposition as a statement that may be true or false and may be centred on fact or ingenuity, which may be dealt with rationally and impartially. The researcher also concurs with Mwamwenda (1995: 99) who reckons that some operational children are unlikely to apply propositional reasoning because they find it difficult to reason logically when they are faced with many *variables*. Furthermore, these children are manipulated by the first *hypothesis*, which makes them unable to deal with other *variables*. For instance, the children may find it problematic to deal with the following scenario.

Mount Kilimanjaro is higher than Mount Aux Sources. Mount Kilimanjaro is lower than Mount Everest. Which has the highest peak?

Some formal thinkers are likely to think abstractly and generalize that, of the three mountain peaks, Mount Everest is the tallest, Mount Aux Sources is the lowest and Mount Kilimanjaro is 'in between'. However, other concrete operational children may reason that Mount Kilimanjaro and Mount Aux Sources are higher than Mount Everest.

4.3.4.2 Hypothetico-deductive Reasoning

The bench mark here is the ability to reason about hypothetical conditions. A supposition is made regarding a position which does not exist in reality, and then the learner is supposed to face the problem as if it were genuine (Mwamwenda 1995: 99). For example, the learner may be asked a hypothetical question such as, *"Suppose you are a farmer - explain factors you will consider before cultivating your fields."* A concrete operational child is likely to say (s)he is not a farmer. The main reason for this type of answer is that the concrete operational child's thinking is limited to concrete objects or events (Dembo 1991: 56). However, Elkind (1968) in Dembo (1991: 56) notes that the formal thinker has no trouble accepting contrary-to-fact suppositions and reasoning. This opinion is echoed by Slavin (1997: 42) who maintains that "*the adolescent can accept, for the sake of argument or discussion, conditions that are arbitrary, that are not known to exist, or even that are known to be contrary to fact*". In this scenario, the formal thinking child is likely to say that (s)he will consider the season and the type of crops (s)he wants to plant and so forth.

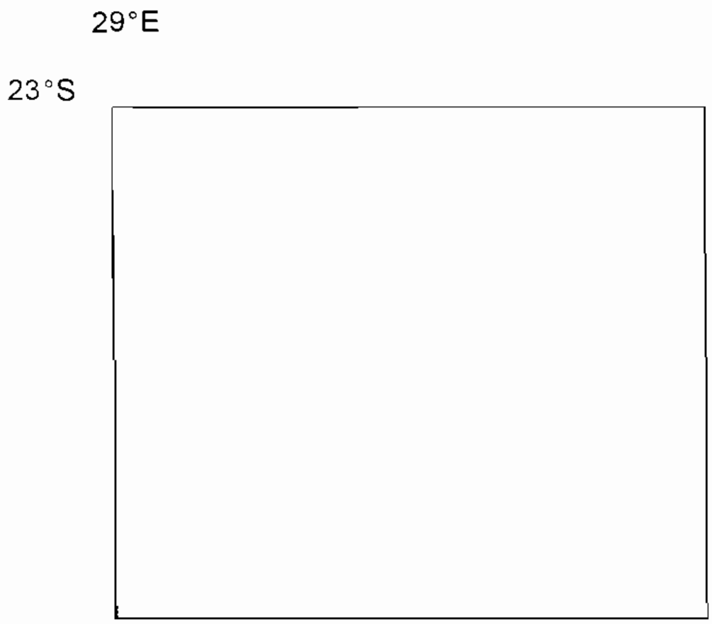
This situation indicates the development of the critical outcomes of *understanding that the world is a set of related systems*. It also promotes the developmental outcome of enabling the learner to *develop entrepreneurial capacities* of farming. Furthermore, the child is likely to *predict* and *infer* the factors (s)he would consider before cultivating the crops.

4.3.4.3 Combinatorial Reasoning

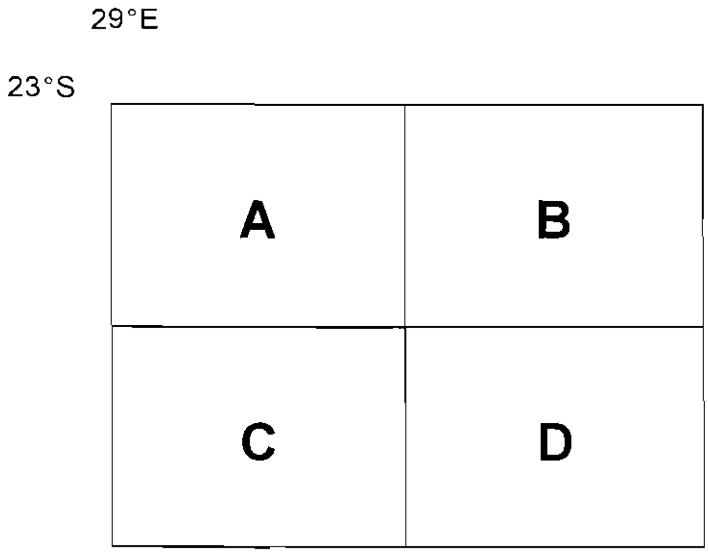
In combinatorial reasoning, all possible answers to a problem are investigated impartially and precisely (Mwamwenda 1995: 99). This is done by keeping some combinations or variables constant while one element is varied. If, after this process a solution cannot be found, another variable is examined while others are held constant. This process will continue until a solution to the problem is arrived at. If this process does not yield the results, it may be essential to explore more than one factor at a time until all possible combinations have been exhausted

(Dembo 1991: 56 and Mwamwenda 1995: 99).

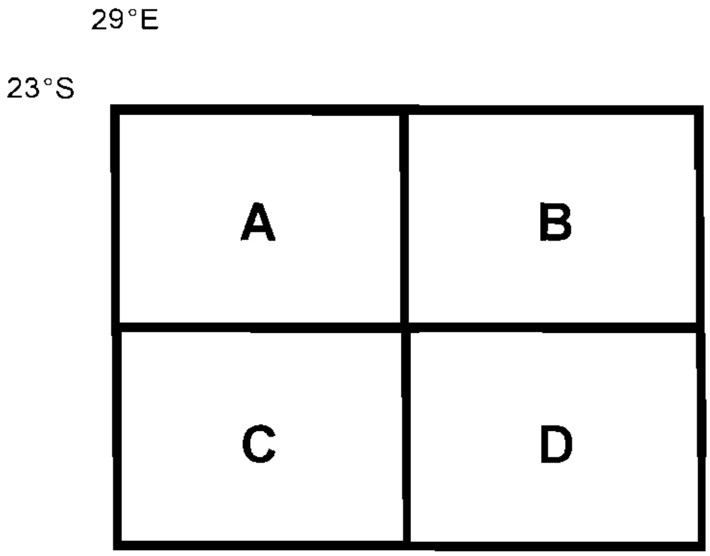
Consider the following example - learners may be requested to employ combinatorial reasoning to use the given four map strips to work out this map code - Louis Trichardt 2329CD which is on the next page.



In order to work out the map code, learners should divide the block into four map strips, i.e. A, B, C and D as indicated in the following diagram.

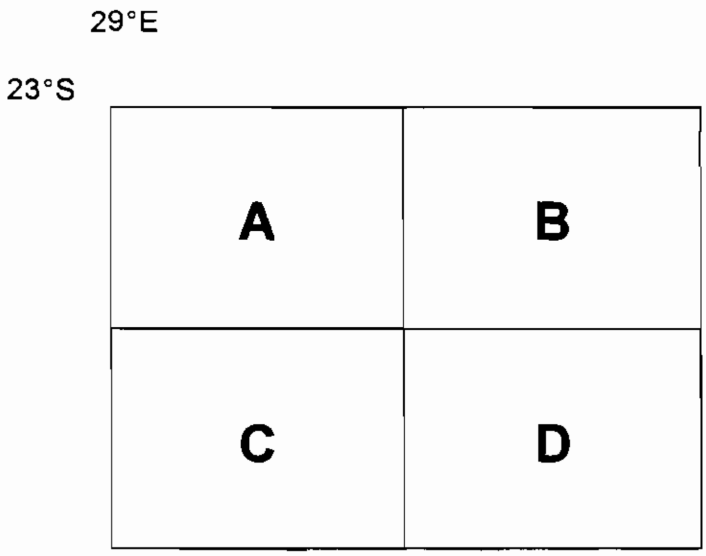


Each of the four blocks should be subdivided into four smaller blocks as indicated on the next page.

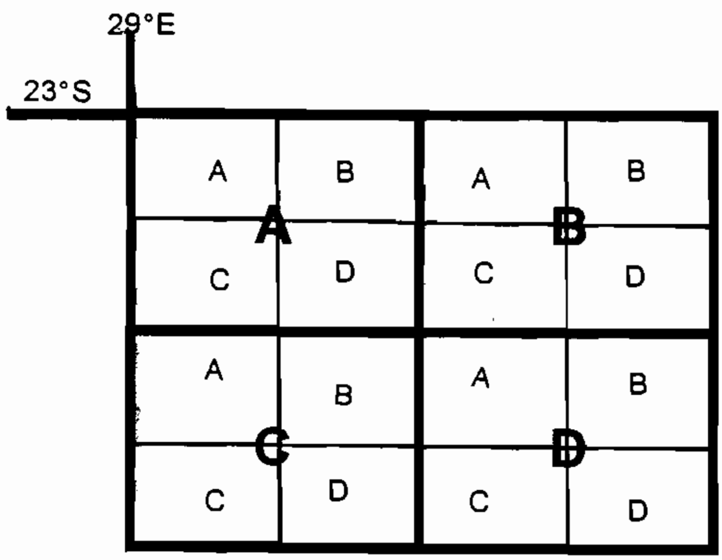


As such, the shaded block is Louis Trichardt 2329CD. This map code may be broken down as follows:

- 23 = 23° South
- 29 = 29° East



Each of the four blocks should be subdivided into four smaller blocks as indicated on the next page.



As such, the shaded block is Louis Trichardt 2329CD. This map code may be broken down as follows:

- 23 = 23° South
- 29 = 29° East

- C = Big block C
- D = Small block D in big block C

This task develops the critical outcome of *identifying and solving problems by using creative and thinking* as the child goes through the process of dividing the blocks and locating the correct location of the map code. This task enables learners to engage in science process skills such as *drawing and observing* the blocks, *classifying* the blocks, *interpreting data* inside the blocks, *predicting* the block which would represent the map code and *communicating* the prediction to the teacher.

4.3.4.4 Proportional Reasoning

Mwamwenda (1995: 99) maintains that proportional reasoning is mathematically based and one mathematical relationship is used to arrive at another mathematical relationship. For instance, this can be useful in the calculation of the time it may take a person to travel a given distance at a given speed. For example, a man wishes to climb a mountain peak which is 1 850 m above sea level. He has already scaled a 900 m peak and he took 80 minutes to reach its top. If he had used a cable car, he would have spent only 20 minutes. The question then is asked - *How many minutes will he spend climbing the peak on foot and by cable car?* What should be determined in this problem is the relationship between the height of the peak and the minutes it takes to climb it on foot and by cable car. A formal thinker will be capable of using the information that the man has climbed a 900 m peak and took 80 minutes on foot and 20 minutes by cable car to solve the problem. The adolescent is likely to approach the equation as follows:

on foot: 1 850 x 80 = 148 000 ÷ 900 = *164 minutes 44 seconds*

or

1 850÷900 = 2, 0555555 x 80 = *164 minutes 44 seconds*

by cable car: 1 850 x 20 = 37 000 ÷ 900 = *41 minutes 11 seconds*

or

1 850÷900 = 2, 0555555 x 20 = *41 minutes 11 seconds*

An equation like this contributes to the development of the critical outcomes of:

- *communicating effectively using visual, mathematical and language skills*;
- *identifying and solving problems by using creative and critical thinking*; and
- *Understanding that the world is a set of related systems.*

Examples given in 4.3.1 to 4.3.4.4 have clearly indicated that Piaget's theory of learning, supplies the capacity to enhance the development and application of science process skills to the teaching of geography. The following section discusses the application science process skills to the geography curriculum.

4.3.5 Application of Science Process Skills to the Teaching of Geography

Consideration of Piaget's theory of learning could enhance the development of science process skills in the teaching of geography. Geography teachers should facilitate and enhance the development of learners' thinking skills through science process skills. This can be developed by exploration, inquiry and discovery learning. Teachers could provide learners with opportunities to discover geographical knowledge through abstract reasoning and active manipulation of concrete materials. The discussion on Piaget's theory (cf. 4.3) has revealed that children are active discoverers, inventors and problem solvers. This implies that learners should be encouraged to interact with their environment and discover knowledge for themselves.

Learners' self-acquisition of knowledge compels teachers to provide opportunities in which learners experience and manipulate geographical phenomena, which implies that content-based teaching should be supplemented with process-based teaching which is likely to develop and promote intellectual activities that may enhance learners' cognitive development.

Eggen and Kauchak (1997: 47) and Mwamwenda (1995: 101) claim that most adolescents as well as adults do not function at the formal operational level. As most learners still operate at the concrete operational level, geography teachers should give learners opportunities to master such mental processes as *observing, classifying, communicating, measuring, inferring and predicting*.

Once learners have acquired and mastered these basic science process skills, teachers should introduce exercises that involve *theorizing, hypothesizing* or *generalizing* about abstract geographical ideas. These should be followed by activities that promote propositional reasoning, hypothetico-deductive reasoning, proportional reasoning and combinatorial reasoning in learners. These activities are likely to develop high order thinking skills in geography learners that may enhance reflective thinking, analysis, synthesis and evaluation. Hence learners are also likely to be equipped with skills that may empower them to solve problems more systematically in the 21st century. The following paragraphs examine how science process skills can be introduced and applied in geography classrooms.