The influence of Inquiry-based Science Education on grade 4 learners' understanding of the particulate nature of matter in the gaseous phase

by

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ABSTRACT

This study aimed to explore the influence of inquiry-based science education (IBSE) in eliciting learner understanding of the particulate nature of matter (PNM) in the gaseous phase. A comparison of the lecture method and the IBSE method was done to identify their effects on enhancing learner understanding on the mentioned difficult science topic. A qualitative pre-test/post-test case study was carried out at two schools in Pretoria, South Africa. Two grade 4 classes were identified at each of the two schools. One of the classes in each school was set aside for lecture teaching and the other was set aside for inquiry teaching. All four classes were initially given a pre-test on the PNM in the gaseous phase. Soon after the pre-test the first group interviews were conducted. At each school one class was then taught using the IBSE method and the other using the lecture method. Soon after the intervention, a post-test was administered to the learners followed by the second group interviews.

Analysis of the pre-test and the first group interview indicated that the initial understanding of learners for both the lecture group and the inquiry group was homogeneous. The continuous model of matter in the gaseous phase emerged as the most prominent view for both the inquiry and lecture group. The results from the post-test and second group interview suggest there was an improvement in particulate understanding in the inquiry group rather than in the lecture group. This seemed to indicate that IBSE was more effective in eliciting particulate understanding as compared to the lecture method

Key words:

Inquiry method, lecture method, constructivism, conceptual change, particulate model of matter, continuous model of matter.

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CCM Conceptual Change Model
IBSE Inquiry-Based Science Education
NRF National Research Foundation
PNP Particulate nature of matter

CHAPTER 1: INTRODUCTION TO THE STUDY

1.0 Introduction

In this chapter the background of the study, the problem statement, the rationale, the purpose of the study, as well as the research questions the study attempted to answer are discussed. The chapter concludes with a description of the sequence followed in the research report.

1.1 Background

The particulate nature of matter (PNM) is an important and abstract topic in science. History has it that even scientists of the past had difficulties in understanding the PNM. They accepted the continuous model for many centuries instead of the particulate model (Abraham, Williamson, & Westbrook, 1994; Boz, 2006; Novick & Nussbaum, 1981). The particulate model appears to be difficult to understand even in modern science. Previous studies have also revealed that most children's initial ideas, just like scientists of the past, are generally continuous views of matter (Novick & Nussbaum, 1981; Novick & Nussbaum, 1978; Pringle, 2006).

Understanding the PNM is important for the learning of chemistry concepts (Haidar, 1997; Novick & Nussbaum, 1978). The study of the PNM paves way for the study of the structure of matter and phase changes (De Vos & Verdonk, 1996; Osborne & Cosgrove, 1983). The PNM provides foundation for the study of diffusion, dissolution process and solution chemistry, chemical reactions, effects of pressure, volume, temperature of gases (De Vos & Verdonk, 1996). The understanding of the PNM may increase learner motivation towards science and may result in increased passes and enrolment in science, and may eventually lead to increase in research and new discoveries in chemistry.

Previous studies have revealed that learners come to school with misconceptions which originate from their interaction with the environment (Posner, Strike, Hewson, Gertzog, 1982). Such misconceptions include the continuous model. Several researches have been done and revealed that the continuous model is quite prevalent in learners (Abraham, Williamson, & Westbrook, 1994; Ayas, Ozmen, & Calik, 2010; Boz, 2006; Novick & Nussbaum, 1981; Stojanovska, Soptrajanov, & Pertusevski, 2012). There is a possibility that this continuous model misconception may be among the causes of failures in science. Identifying misconceptions of learners at their early stages may be useful in learning advanced science topics, because certain misconceptions may persist from preschool to high school (Ayas, Ozmen, & Calik, 2010).

Previous researches have also revealed that learner-centred modern teaching approaches may help to reduce misconceptions and increase understanding (American Association for the Advancement of Science, 2000; National Research Council, 2000; Department of Basic Education, 2012; Marx, Blumenfeld, Krajcik, Fishman, Soloway, Geier, Tali Tal, 2004). The learner-centred approach to teaching may help to exchange the continuous model usually present in the learners' minds, with the appropriate scientifically accepted particulate model. One such modern teaching approach is the inquiry-based science education (IBSE).

IBSE is a teaching and learning approach where learners are engaged in investigations by observing, questioning, planning, experimenting, communicating, and reporting just to mention a few (Abd-El-Khalick & Akerson, 2004; Anderson, 2002; Bybee, 1997; Mullis, Martin, Ruddock, O'Sullivan, Preuschoff, 2011; Ozgelen, Yilmaz-Tuzun, Hanuscin, 2012). This approach has been observed to yield better understanding of concepts by learners than the lecture methods (Adams & Mabusela, 2013; Abd-El-Khalick, Boujaoude, Duschl, Lederman, Mamluk-Naaman, Hofstein, Taun, 2004; Oche, 2012). However, research has also proved that introducing IBSE at high school level failed to yield good results (Areepattamannil, 2012). Some researchers have attributed this failure to yield good results at high school to prolonged use of rote learning and teaching methods (Areepattamannil, 2012).

The current research focused on the topic of PNM in the gaseous phase because it is very important, since it forms the backbone of chemistry, an important science subject

(De Vos & Verdonk, 1996; Haidar, 1997; Novick & Nussbaum, 1978; Osborne & Cosgrove, 1983). This topic has been observed to be difficult to learners and many misconceptions on the topic have been identified (Abd-El-Khalick and Akerson, 2004; Anderson, 2000; Ozgelen, Yilmaz-Tuzun, Hanuscin, 2012; Ramette & Haworth, 2006). Therefore, a comparison of the lecture method and the IBSE was made to determine their effectiveness in promoting higher level of understanding of a difficult grade 4 science topic.

1.2 Problem statement

The current research investigated the influence of IBSE on grade 4 learners' understanding of the PNM in the gaseous phase. The topic PNM starts at grade 4 and is the backbone of chemistry. The performance of South African learners in science is generally low (Mullis, et al., 2011). This low performance may be caused by many factors. Some of the factors causing poor performance include lack of textbooks, under-resourced laboratories, lack of qualified educators, the use of inappropriate teaching and learning methods, lack of conceptual understanding on the part of learners, just to mention a few (Mullis, et al., 2011).

The gaseous phase was chosen because it forms the foundation of many topics in the study of chemistry therefore is very important (De Vos & Verdonk, 1996; Novick & Nussbaum, 1978). The topic PNM in the gaseous phase has been identified to be difficult for learners due to the properties of gases like; being usually invisible, colourless, and/or being odourless (Ramette & Haworth, 2006). These properties of gases make learners not to be able to visualize and recognize the existence of gaseous substances (Ramette & Haworth, 2006). Previous study by Novick and Nussbaum (1985) also revealed that in the past scientists gradually evolved from continuous model to particulate by studying the gaseous phase. It seems therefore much easier for learners to understand the particulate nature of matter in the gaseous phase than in the solid or liquid phases due to the observable effects in classroom demonstrations when gases are compressed, when they expand upon heating and when they are allowed to diffuse from high to low concentrations (Novick & Nussbaum, 1981).

If learners do not understand the basics of the PNM at their early grades, they may find difficulties to understand chemistry as a subject at higher grades (Stojanovska, Soptrajanov, & Pertusevski, 2012), because some misconceptions like the continuous model, are resistant. The misconceptions may be caused, among others, by inappropriate teaching approaches which are sometimes referred to as school-made misconceptions (Barke, Hazari, & Yitbarek, 2009). Other sources of misconceptions are the science text-books, educator misconceptions, peer misconceptions (Stojanovska, Soptrajanov, & Pertusevski, 2012), or other sources are before the learners attend school (Bolat & Sozen, 2011; Posner, et al., 1982; Pringle, 2006). The prevalent continuous model, which is a misconception, may be one of the causes of low performance in science (Mullis, et al., 2011).

The low performance prevalent in South African science may also be due to lack of understanding of science concepts by the learners, therefore, exposing learners to IBSE at that early stage may motivate learners and improve conceptual understanding. IBSE may help learners to develop higher cognitive skills at primary level which are important for use at high school and tertiary level (Bloom, 1956). This study aimed at comparing the effects of IBSE and lecture teaching in enhancing learner understanding of the particulate nature of matter in gaseous state.

1.3 Rationale

IBSE has for many years, been viewed as a recommendable approach to science teaching and learning worldwide from primary to tertiary levels (Anderson, 2002; Dudu & Vhurumuku, 2012; Hofstein & Lunetta, 2004; Minner, Levy & Century, 2010; Abd-El-Khalick & Akerson, 2004; Mullis, et al., 2011). IBSE is recommended by the Department of Basic Education (2012) but seldom practiced in South Africa (Ramnarain, 2010). Since IBSE is associated with good science teaching in many countries of the world, the current research investigated the influence of IBSE on grade 4 learners' understanding of the topic of PNM in the gaseous phase in South African primary school science.

IBSE has been tried in many countries of the world and has been found successful with regard to performance and eliciting understanding (Abd-El-Khalick, et al., 2004; Dudu & Vhurumuku, 2012; Ozgelen, Yilmaz-Tuzun, Hanuscin, 2012; Tlala, 2011). However, in South Africa, studies on IBSE has been conducted at higher levels of education with little research having been conducted at lower grades. South Africa advocates for IBSE (Department of Basic Education, 2012), but learners still perform poorly in science (Mullis, et al., 2011). This poor performance may be due to prolonged use of rote learning and teaching methods before using IBSE (Areepattamannil, 2012). The fourth grade was chosen for this study, since it is when learners start science, before they have received formal education in science, to avoid possible interference of previous teaching approach (Areepattamannil, 2012; Department of Basic Education, 2012).

The current research therefore focused at primary school level to explore possible benefits IBSE may have on learner understanding of the PNM. The research was done by comparing IBSE teaching with lecture method on the extent to which a teaching approach influences learner understanding of difficult science concepts at primary school level. The focus was on learners' understanding and not only on their performance. One of the reasons why the focus was on understanding is that learners may perform well by memorization. The conceptual change model (CCM) Posner, et al., (1982) used, focused on eliciting learners' awareness of their preconception to effect a possible conflict which may result in a possible conceptual change.

The other reason for focusing on understanding is that it may give room for a learner to apply what was taught (Anderson & Krathwohl, 2000). A learner who understands matter in the gaseous phase may understand matter in solid or liquid phase much easier than one who does not understand (Novick & Nussbaum, 1981). The understanding the learner gets may be of use even in other topics or subjects the learner may study even in the future. When learners' mental models are based on the scientifically acceptable particulate conception, grasping of the chemical processes inherent in chemical reactions may be easily achieved.

The particulate model is the scientifically accepted model of matter. The particulate model forms the backbone for the study of chemistry. It provides answers to understanding of the abstract processes studied in chemistry, such as, chemical reactions, atomic and molecular structure, physical properties, just to mention a few (De Vos & Verdonk, 1996; Osborne & Cosgrove, 1983). If learners' understanding is the scientifically accepted particulate model, then their understanding of chemical processes may be much easier.

The learners who have a direct hands-on experience during IBSE may get direct observations and experiences. These learners may develop useful problem-solving skills and habits of the minds that are long-lasting for their future study, work and life experiences. These learners may therefore perceive science as easy, understandable, interesting and motivating (Avery & Meyer, 2012; Mattheis & Nakayama, 1988; Minner, Levy & Century, 2010). This increased understanding of the concepts may act as motivation for the learners' to desire to know more. Thus, the learners may develop intrinsic motivation towards their learning of science.

To my knowledge there seems to have not been similar research done previously in South Africa at primary school level. The study may provide evidence on how teaching approaches may influence South African learners' conceptual understanding. Such evidence is important for educational authorities when choosing the teaching approach that is effective for learners' development of higher cognitive skills required for learning science at higher levels of education. The study results may also demonstrate the importance or not, of using IBSE at lower primary school level.

1.4 Purpose of study

The purpose of my study was to explore the influence IBSE has compared to the lecture method in promoting grade 4 learners' understanding of the PNM in the gaseous phase.

1.5 Research Questions

The study attempted to answer the following research questions:

Primary research question

How does an inquiry-based instructional approach, as compared to a lecture approach, influence grade 4 learners' understanding of the PNM in the gaseous phase?

Secondary research questions:

In order to address this question, the following two sub-questions were explored:

Sub-research question 1: What initial understanding do grade 4 learners demonstrate on the topic PNM in the gaseous phase?

Sub-research question 2: What level of understanding do learners in the inquiry and lecture groups have after being taught with IBSE and lecture methods respectively?

1.6 Assumptions

The research was based on the following assumptions.

1. That any increase in understanding of either the class taught by IBSE or by the lecture method was attributed to the teaching method used.

2. That the initial misconceptions learners have may be changed by using either IBSE or lecture method.

1.7 Structure of the dissertation

In the first chapter the background, the statement of the problem, the rationale for the study, the aim of the study and the research questions were discussed. The second chapter reviews literature relevant to the study. In the third chapter the research methodology is outlined. Chapter four presents an analysis and discussion of the results. In conclusion, chapter five discusses the findings of the study, the limitations as well as areas for further research. The list of references and the appendices then follow for easy cross-referencing.

CHAPTER 2: LITERATURE REVIEW

2.0 Introduction

The chapter commences with a description of the previous research conducted on the topic PNM in the gaseous phase. Afterwards is a discussion of the methods used in similar studies and the results obtained. This is followed by a description of literature about the two instructional approaches, the lecture method and the IBSE method which were used in the current study. The chapter concludes with a discussion of the conceptual framework for the study.

2.1 Background

Before the dawn of the 20th century it was generally believed that matter is continuous (Novick & Nussbaum, 1981). Scientists did not conceptualize the particulate nature as they do nowadays. Previous studies however have had the likes of Lucretius in the 1st century BC who proposed a particulate conception but the idea was not accepted (Novick & Nussbaum, 1981). Hero of Alexandra had a similar particulate conception with the presence of a vacuum in the 1st century AD, but again the idea did not receive recognition. This showed that human ideas of matter were generally continuous as opposed to particulate (Abraham, Williamson, & Westbrook, 1994; Boz, 2006; Novick & Nussbaum, 1981). The continuous conception of matter which was accepted for centuries by scientists of the past is generally what learners of today hold (Novick & Nussbaum, 1981). It seems that this continuous conception may be a hindrance for learners when they are introduced to particulate matter, for example atoms, electrons, neutrons and molecules. The continuous view may affect learners' understanding of physical properties like evaporation, vapour pressure, boiling, melting and dissolving, just to mention a few. Modern science accepts the particulate nature of matter (Abraham, Williamson, & Westbrook, 1994; Boz, 2006; Novick & Nussbaum, 1981).

2.2 Research on understanding the particulate model of matter

Previous studies have revealed that learners understand the particulate nature of matter better in the gaseous phase than in any other phase. Teaching matter in the gaseous phase is better understood than in the other phases because of the strategies used for instruction such as compression and expansion, which are observable (Novick & Nussbaum, 1981). The activities, which include experiments and demonstrations, create possibilities for inquiry and elicit understanding.

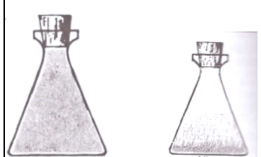
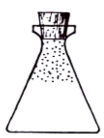
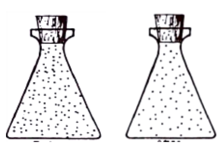
In the gaseous section of the study by Novick and Nussbaum (1981), learners were made to draw air in a container assuming that they had magic glasses which could allow them to see air. So the learners made their drawings to show how they believed air looked like. These were grade eight learners who had received teaching on the topic in grade seven. During their teaching in grade seven, the learners were taught properties of matter like fluidity, compressibility, decomposition, separation and mixing. They were also taught the PNM which included atoms and molecules.

In the first task the learners were shown a flask fitted with an evacuation pump. The learners were first taught how the evacuation pump works. They were then asked to draw air before and after the use of a vacuum pump imagining that they had magic glasses which would allow them to see the air. Most of the learners responded by shading the container showing a continuous conception and a few had particulate conception as shown by dots in their drawings. In the second task the learners were given sets of drawings done by other learners in answering the first task. In this case learners were asked to choose the appropriate drawings before and after the use of a vacuum pump. The learners who in the first task had the continuous conception were given shaded sets first and then afterwards they were given sets that had dots.

A third task was for learners to report what they thought was between the dots in the drawings. This task was probing for the idea of empty space between particles. The fourth task probed learners to explain why particles could concentrate in the upper part of container without falling down. This idea looked for the intrinsic motion of particles.

The sample for the study had 150 learners from nine Israeli urban schools. In the first task 64% of the learners suggested that air is made up of particles. In the second task 78% of the learners chose diagrams representing the particulate form of air. Of these learners one in six believed that particles were not evenly scattered in the container but rather confined to some particular part of the container. This showed the retention of continuous conception by learners.

Table 2. 1 Learners' conceptions in the study by Novick and Nussbaum, 1981

Model	**Drawings**	**Description**
Continuous		Continuous conception shown by smooth shading. Whole container may be shaded or part of the container.
Continuous animistic		Shading only at the top accompanied with a description that *"air wants to go up" or "air is resting"* showing animal behaviour.
Continuous empty		Air is shaded in spots but there is empty space between the spots. There is an idea of empty space but only between clusters
Particulate animistic		Air represented by dots. Dots concentrated at the upper part only. Accompanied with *"air wants to stay at the top"* which is animal behaviour
Particulate		Air represented by dots in whole container depicting particulate model. Almost even space between particles.
Continuous particulate		Air represented in dots in clusters with empty space between the clusters of air.

In the third task only 35% of the sample acknowledged the existence of an empty space. The learners suggested that between the particles there should be more particles. Some learners suggested there is dust between the particles. Others suggested there is oxygen; others suggested air, dirt, germs or unknown vapours. In task four 50% of the learners suggested that particles have intrinsic motion. There were some responses like *“the particles want to rise”* which showed animistic conception.

The conceptions of learners as observed in the study were classified as continuous, continuous empty, continuous animistic, particulate animistic, particulate, continuous particulate, and the empty conceptions. The drawings are as shown in the table 2.1 above.

In Turkey, Boz (2006) explored how grades six to eleven’s views of the particulate nature of matter phase changes. The focus was on the arrangement and movement of particles in solid, liquid and gas, and the application of the particulate conception during phase changes. The results revealed that the older children did not apply particulate ideas in their explanations. A similar result was found in the research done by Haidar and Abraham (1991) on grades eleven and twelve learners. The learners were investigated on their applied and theoretical knowledge of the particles in the three phases. The learners gave macroscopic explanations in the tests and did not mention atoms or particles. And a research by Abraham, Williamson and Westbrook (1994) on grades nine, eleven and twelve investigated the learners’ reasons for constant temperature of ice during melting. Less than 6% of learners in each grade used particulate terms in the explanations.

These studies have one result in common: learners’ initial conception is generally not particulate but rather continuous. This is in line with the difficulty scientist of the past had in accepting the particulate nature of matter (Novick and Nussbaum, 1981). Educators should therefore take into consideration the initial conception of learners to devise appropriate teaching strategies to teach the scientifically accepted particulate conception of matter. Novick and Nussbaum (1981) described the conceptual conflict strategy that would initiate and encourage desired conceptual change in the same way as Posner, et al, 1982, and Hewson, 1992).

2.3 Studies on teaching and learning

Conceptual change, from a social constructivist point of view, is a process where humans construct their own knowledge within a social context (Hewson, 1992). According to Hewson (1992), conceptual change may lead to a change in the original conception in addition to assimilation of new knowledge. The conceptual change model (CCM) involves the interaction between the new and the already existing conception. The CCM is based on two assumptions. The first is that major conceptual changes are a result of some conceptual conflict between the preconception and contradicting evidence. The second assumption is that, unless learners are quite aware of their own existing conception, they are unlikely to sense a genuine conflict. The exposing event creates awareness (Posner, et al., 1982). In the exposing event the educator initiates and guides learner discussions so that by a hands-on activity the learners would understand their pre-conception better. When learners are given chance to discuss their observations and try to explain them, this may lead to learners having a deeper awareness of their pre-conception. When the pre-conception and the examined phenomenon differ, it leads to a conflict of ideas, which is the discrepant event. If the learners can understand the new conception and fit it within pre-existing conceptions then it is intelligible. If the learner can believe that the conception is true then it is plausible. If the learner can find the new conception to be useful then the idea is fruitful. When the three stages are all met, then conceptual change occurs (Hewson, 1992; Novick & Nussbaum, 1981; Posner et al., 1982).

Conceptual conflict strategy proposed by Novick and Nussbaum (1981)

Novick & Nussbaum (1981) sought for more effective teaching strategies which would result in initiating and encouraging conceptual change. Just like Posner et al. (1982), they concurred that major conceptual changes are initiated as a result of some conceptual conflict between the pre-conception and contradicting evidence. This is the discrepant event. Their second assumption was that for learners to sense a genuine conceptual conflict, they should be clearly aware of all elements of their pre-conception. This means that for a beneficial conceptual conflict the pre-conception should be clearly exposed to the understanding of the learners. Novick & Nussbaum (1981) asked learners to make drawings of air in different containers assuming they wore magic glasses. Most of the drawings done by learners showed continuous model. The learners were then led through guided discussion. This discussion according to Novick & Nussbaum (1981), if properly guided, would lead to learners' full awareness of their pre-conception. Compressing of the air was then demonstrated. This led to conceptual conflict because if air was continuous then it would not be compressible. This was the discrepant event.

The key, therefore, is on the teaching approach used by educators to allow learners to effectively experience discrepant events. The teaching approach should be effective in eliciting conceptual conflict, so that the learners may experience all the above mentioned stages, then conceptual change may occur.

In the current study, the focus was therefore on investigating the effectiveness of two teaching approaches, the lecture method and the inquiry method, in eliciting conceptual change in learners' understanding of matter in the gaseous phase. Since the goal of teaching is to effect conceptual change, the research sought to compare the effectiveness of the lecture and the IBSE methods on learner understanding of the PNM. The study by Pascarella and Terenzin (2005), indicated that learner-centred methods, such as IBSE, may result in learners achieving better grades and understanding, and that learners may start having more confidence in their studies.

There are different methods used for teaching. The most common ones used since many years ago fall under the teacher-centred approach. These are the lecture method, lecture-demonstration and the historic method, and many more. These methods of teaching give the educator full control of the class and all the activities. Learners usually have little or no say about the learning process and are passive participants (Saidi, 2004). Usually the learners can hardly ask questions to be clarified by the educator.

Consequently, the educator may not be aware of the pre-conceived knowledge and understanding of the learners (Ozgelen, Yilmaz-Tuzun, & Hanuscin, 2012; Saidi, 2004; Singh & Nath, 2005; Veer, 2004).

Modern research in education has revealed that learners usually have some pre-conceived knowledge on almost every topic of study (Coetzee & Imenda, 2012; Pringle, 2006; Szalavitz, et al., 2004). This discovery led to the development of learner-centred methods of teaching. These methods include, among others, problem solving, discussion, the inquiry method, and the laboratory method, just to mention a few. These methods consider the learners' preconceptions in every topic of study and use those preconceptions as a starting point towards achieving correct understanding and even acquiring new knowledge (Ozgelen, Yilmaz-Tuzun, & Hanuscin, 2012; Pringle, 2006; Saidi, 2004; Singh & Nath, 2005; Veer, 2004).

The current study compared the effectiveness of the lecture method and the inquiry method in eliciting learner understanding of matter in the gaseous phase. The lecture method was used in this study because it seems to be the method that is commonly used by most educators. The inquiry method is one of the modern methods said to provide better understanding and performance of learners (Adams & Mabusela, 2013; Abd-El-Khalick, et al., 2004). The inquiry method also comes close to achieving the learner-centred approach recommended by the South African Department of Basic Education (Alebiosu, 2005; Department of Basic Education, 2012); Oche, 2012).

2.4 The particulate nature of matter in the gaseous phase

The PNM in gas, liquid and solid phase is prescribed in the syllabus by the Department of Education (Department of Basic Education, 2012) starting at grade 4. This topic is abstract and requires conceptual understanding rather than rote learning. The topic PNM is fundamental to the understanding of the chemistry topics to be covered in higher grades. A valid description of the PNM in the gaseous phase should incorporate the following ideas currently accepted by scientists as consisting of the following properties (Ayas, Özmen & Çalik, 2010):

- Gases are made up of particles.
- Most gases are invisible.
- Gases fill the whole container or space.
- Gas particles are in continuous random motion.
- There is space between the particles of a gas.
- Particles of gas are evenly spaced leaving a vacuum between them.
- Gases can be compressed.
- Gases can be displaced from containers by solids or liquids.

These properties have also been outlined in the department of basic education's curriculum policy document as the content that needs to be taught at grade 4 level (Department of Basic Education, 2012).

These are some of the reasons why the topic 'PNM in the gaseous phase' was chosen for the purposes of this study. The initial knowledge of learners is usually a mixture of correct conceptions and misconceptions. Some of the misconceptions in this topic are the continuous or animistic conceptions (Novick & Nussbaum, 1978). In the continuous model learners would have the assumption that particles of gas are in a continuous arrangement without spaces between them. The animistic misconception is that learners understand gas particles as animals which can think and decide what to do; either to run away or go somewhere. The researcher searched for the manifestation of such misconceptions when analysing data collected through learner responses in the current study. The aim was to classify learners' conceptions as continuous, continuous empty, continuous animistic, continuous particulate, and/or particulate.

The analysis of previous studies shows that the continuous conception is quite persistent. Previous studies have revealed that continuous conception is dominant in learners at high school level (Abraham, Williamson, & Westbrook, 1994; Boz, 2006; Novick & Nussbaum, 1981). Scientists of the past also took many centuries to accept the PNM (Novick & Nussbaum, 1981). Continuous conception of matter hinders the understanding of chemical knowledge which is believed to be acquired at three levels of the macro, sub-micro and representational levels (Johnstone, 2000). Learners may find difficulty in understanding the chemical and physical properties of matter as a result of the dominance of the continuous conception (Adams & Mabusela, 2013). It may be suggested that learners may have the continuous conception model as a result of the rote learning they are exposed to by some of their educators. From literature reviewed, it appears the continuous conception is inherent; therefore, if educators also have such a misconception, they may transmit it to their learners during the lecture method (Pringle, 2006).

2.5 The inquiry-based science education (IBSE)

In this study IBSE is defined as a cycle of stages in the learning process through which learners are exposed to a learning material with necessary resources and guidance promoting analytical thinking and reasoning (Bybee, 2010; Kurumeh, Jimin, & Mohammed, 2012). The IBSE model used in the study is based on the Bybee's (1997) 5Es model. The model's 5Es stand for the engage, explore, explain, elaborate and evaluate stages. This is explained in detail in section 2.5.1 below

2.5.1 Bybee's 5Es instructional model (inquiry method)

The original intention of the 5Es instructional model is based on a constructivist view of learning. The constructivist model acknowledges that learners have pre-conceived ideas before coming to school. The initial ideas the learners have are usually a mixture of correct and incorrect ideas (Coetzee & Imenda, 2012; Ozgelen, Yilmaz-Tuzun, & Hanuscin, 2012; Pringle, 2006). The incorrect ideas may be replaced by more sensible ideas by using a suitable teaching approach (Bybee, 1997). The IBSE lesson design and execution used in the current study were based on Bybee's 5Es instructional model. This model was used to guide the teaching approach to ensure its inquiry element. It was employed as a basis for making sure that where IBSE is reported to have been used it could be assessed on a checklist to confirm that this was indeed the case (Bybee, 1997).

In using IBSE following the 5E model, the first stage is to engage the learners on the subject matter. The second stage is exploration during which the educator observes the learners and asks them leading questions while they carry out investigations. The third stage is characterized by learners explaining their findings with justification to the educator and their peers. The fourth stage is when the educator provides learners with new activities where they can apply the acquired understanding and, finally, both the educator and learners evaluate the progress and understanding (Bybee, 1997). This involvement allows the learners to acquire skills and attitudes that encourage learners to seek solutions to questions and problems while constructing new knowledge (Hewson, 1992). IBSE is based on John Dewey's philosophy that education begins with the curiosity of the learner (Harvey & Daniels, 2009). This constructivist teaching approach places the responsibility for learning on the learner and encourages learners to arrive at deeper understanding of concepts by themselves, through the development of mental constructs (Abd-El-Khalick, et al., 2004; Anderson, 2002; Ozgelen, Yilmaz-Tuzun, & Hanuscin, 2012). IBSE, therefore, is an approach which tries to elicit interest in the learners as they go through the inquiry stages (Kurumeh, Jimin, & Mohammed, 2012). In this study, therefore, the inquiry group was taught following the guidelines and recommendations from Bybee's 5Es model (1997). This model served as a guide for activities of both the learners and educators and was aimed at developing learners' understanding in the target topic.

IBSE assumes that learners have preconceived ideas on almost every topic of study (Bybee, 2010; Coetzee & Imenda, 2012). The first stage, therefore, in IBSE is to identify the prior knowledge of the learners so as to teach them from the known to the unknown. This shall be elaborated on in the conceptual framework in section 2.7.

IBSE emphasizes understanding rather than memorization (Alkaher & Dolan, 2011; Green, Elliot, & Cummins, 2004; Ozgelen, Yilmaz-Tuzun, & Hanuscin, 2012; Pringle, 2006). It also focuses on the generation of useful and applicable knowledge through investigation (Furtak, Seidel, Iverson, & Briggss, 2012). IBSE focuses on activities that promote understanding of the natural and human-designed worlds through direct and active involvement of learners.

Table 2. 2 Educator and learner activities in an IBSE class based on Bybee's 5Es model, Bybee (2011)

Lesson stage	**Educator's activities**	**Learner activities**
Engage	Raises questions which generate interest and curiosity. Pre-conceptions are observed here. Reading or demonstration.	Shows interest and asks questions about why certain things happened and makes suggestions.
Explore	Provides time for learners to work. Educators observes and listens, asks probing questions.	Thinks creatively. Tests predictions and hypotheses. Records observations and conclusions.
Explain	Educator asks for clarification and evidence using learners' previous experiences. Encourages learners to explain their observations in their own words.	Explains to others. Listens critically to educator and peers. Uses recorded observations to explain.
Elaborate	Educator expects learners to apply scientific concepts and skills. Reminds learners of alternative explanations.	Applies new findings and definitions in similar situations. Uses previous information to ask questions, propose solutions.
Evaluate	Observes and assesses learners. Allows learners to assess themselves. Asks open-ended questions.	Demonstrates understanding of concept or skills. Answers open-ended questions using observations, evidence and previous experiences. Self-evaluation.

It seeks appropriate solutions to questions and issues (Abd-El-Khalick, et al., 2004; Anderson, 2002; Furtak, et al., 2012; Ozgelen, Yilmaz-Tuzun, & Hanuscin, 2012; Mullis et al., 2011; Szalavitz, et al., 2004). IBSE may allow learners to develop understanding of science, develop inquiry skills (identifying problems, generating questions, designing and conducting investigations, develop critical thinking abilities, scientific reasoning) and enable learners to get a deeper understanding of content (Abd-El-Khalick, et al., 2004;

Cakici & Yavuz, 2012; Dudu & Vhurumuku, 2012; Minner, Levy, & Century, 2010; Tlala, 2011). All these abilities may improve learners' scientific literacy and may also motivate learners to develop into future researchers who may possibly contribute to the body of knowledge in their future careers.

IBSE has been found to succeed greatly, especially among learners who were historically low achievers (Avery & Meyer, 2012; Kolkhorst, et al, 2001; Marx, et al., 2004). South African learners are among the historically low achievers in Mathematics and Science (Department of Basic Education, 2012; Mullis, et al., 2011). Therefore, the use of IBSE, as prescribed by the Department of Basic Education of South Africa, may have positive effects on learner understanding of science content and scientific processes. IBSE has the possibility of capturing the curiosity of the young learners. The learners may then be motivated to learn science and develop understanding.

Literature shows that IBSE has been extensively practiced and researched. Countries all over the world including the United States of America, Europe, Asia, Australia and Africa have practiced IBSE (Areepattamannil, 2012; Avery & Meyer, 2012; Cakici & Yavuz, 2012; Marx, et al., 2004). In Africa, especially South Africa, however, the study and practice of inquiry has not been so prevalent. Some research has, however, been done in South Africa on the grade ten and eleven and university and college levels (Dudu & Vhurumuku, 2012; Tlala, 2011). In most cases, inquiry has been observed to yield better results, better understanding and better motivation towards the learning of science (Harvey & Daniels, 2009; Oche, 2012). It seems there is no evidence of research on IBSE being conducted in South Africa at grade 4 level.

Previous research on IBSE has focused mainly on pre-service educators and high school students (Abd-El-Khalick, et al., 2004; Areepattamannil, 2012; Avery & Meyer, 2012; Dudu & Vhurumuku, 2012; Minner, Levy, & Century, 2010; Oliver, 2007; Ozgelen, Yilmaz-Tuzun, & Hanuscin, 2012; Tlala, 2011) with less focus on the primary school level (Cakici & Yavuz, 2012). The current research, focused on the South African grade 4 context, may contribute to expand the body of knowledge about the effects of IBSE at primary school level.

2.5.2 Advantages of IBSE

One of the advantages of IBSE is that it is not confined to one source of information. The learners have a wide range of information sources which they may use to acquire knowledge (Adams & Mabusela, 2013; Kompa, 2012). Learners can learn in context and, therefore, develop an in-depth understanding of the content. This gives learners a chance to discover new knowledge which may not be in any prescribed text-book. IBSE promotes strong self-directed learners who are able to face real-life problems as they leave school (Kompa, 2012). IBSE fosters the development and use of high level cognitive and metacognitive skills (Anderson & Krathwohl, 2000; Bloom, 1956). These high order cognitive skills form the basis of investigative skills used in searching information, they are analysing, synthesizing, evaluating and organizing communicating of findings. These skills show learners' understanding of the content and not just memory recall (Bloom, 1956). The cognitive and metacognitive skills are helpful for learners to continue research so as to discover more knowledge. Lastly, inquiry allows active participation of learners, encourages learners to have dialogue and learners are engaged in inductive and systematic thinking (Alebiosu, 2005).

2.5.3 Shortcomings of IBSE

A study by Kirschner, Sweller and Clark (2006) revealed that unguided or minimally guided instruction may not be effective in eliciting learner understanding. Another constraint of IBSE is the amount of time the implementation of IBSE requires (Kirschner, Sweller, & Clark, 2006; Kurumeh, Jimin, & Mohammed, 2012). School syllabuses are structured in a way that there is limited time for implementing IBSE. Also the issue of mandatory assessment may hinder IBSE in higher grades like grade twelve but little effect may be felt at the grade 4 level because there is no mandatory assessment needed. Another hindrance to implementation of IBSE is availability of resources. A further limitation is possibly lack of skill of the educators in IBSE and in the science content knowledge (Bybee, 1997). Kurumeh, Jimin and Mohammed (2012) stated another disadvantage of IBSE as that of the frustration learners experience when they fail to get the desirable solution.

Some possible disadvantages of inquiry-based teaching could be less coverage of topics, lack of teaching space in the classrooms and the problem of rigid timetables (Alemu & Schulze, 2012). Lastly, another setback of inquiry-based teaching may be that of noisy classes as learners will be involved in a lot of discussions (Alemu & Schulze, 2012; Pascarella & Terenzin, 2005).

2.6 The lecture method

The lecture method is a one-way teaching method where the educator makes oral presentations of the content and learners listen to the educator and take notes (Oche, 2012). In the lecture method the educator is the master of all knowledge and assumes that learners do not know anything in any topic (Adams & Mabusela, 2013). The educator has the role of telling the learners what they need to know. There is usually a one-way communication from the educator which results in rote learning as learners just memorize facts instead of seeking understanding (Adams & Mabusela, 2013; Kompa, 2012; Szalavitz, et al., 2004).

2.6.1 Bybee's 5Es instructional model (lecture method)

Bybee (2010) provides a schedule with descriptions of educators' and learners' behaviours which are inconsistent with the 5E model for IBSE and which are exemplary of the lecture method. The schedule was quite useful for guiding the design and execution of the teacher-centred method. In the current study the lecture method was guided by the activities attributed to the teacher-centred approach in Bybee's (2010) model.

This design being a lecture approach, during the 'engage' stage the educator explains concepts by giving definitions and lectures. The learners ask for the right meanings from the educator and writes what the educator says word for word. In the second stage of 'exploration', the educator provides step-by step procedures on how to solve problems and gives the learners the correct answers. The learners passively get what the educator gives them. The learners do not pay much attention on how the problems are solved but rather on what the educator says. Table 2.3 below shows in more detail, the activities for both educator and learners in a lecture group following the model by Bybee (2011).

Table 2. 3 Educator and learner activities in lecture class based on Bybee's 5Es model, Bybee (2010)

Lesson stage	Educator's activities	Learner activities
Engage	Explains concepts, provides definitions and lectures.	Asks for right answers and explanations.
Explore	Provides information on how to work through the problem. Tells the learners answers and where they are wrong. Gives information and facts that solve problems.	Sits back, and expects other learners to do the thinking. Does not think of other solutions except those from the educator.
Explain	Does not solicit explanations from learners. May accept explanations from learners but without justification. Introduces unrelated skills.	Accepts explanations without justification. Proposes explanations without much thought. Brings irrelevant ideas and examples.
Elaborate	Gives definite answers. Provides step-by-step procedure to get to the answer. Lectures.	May take down answers word for word, ignores previous information and advice. Neglects to record data.
Evaluate	Tests vocabulary words and isolated facts. Introduces new ideas and facts. Promotes open-ended discussion unrelated to the concept.	Draws conclusions without evidence. Uses 'yes' or 'no' without justification. Offers memorized facts. Cannot give justification of his answer.

During the 'explain' stage the educator does all the explanation without asking for explanations from learners. Sometimes the educator may accept explanations from learners but without justification. The learners also accept what the educator says without asking for justification. The learners do not apply much reasoning to the explanations provided. During 'elaborate' stage the educator gives definite answers and step-by-step procedures to get to the answer. The learners may pay no attention and may neglect to record data or take down notes. In the last stage, the 'evaluate' stage, the educator tests vocabulary and isolated words. The educator promotes open-ended discussion unrelated to the concept. The learners do not seek evidence when getting to conclusions. The learners opt to memorize rather than reason (Bybee, 2010).

2.6.2 Advantages of the lecture method

Advantages of the lecture method may include the time factor. This approach is quite useful for quick completion of a topic of study but without consideration for the understanding of learners (Adams & Mabusela, 2013; Szalavitz, et al., 2004). The educator is the dominant speaker in the class and the learners are generally passive listeners (Bybee, 2010). The educator therefore may cover a lot of topics in a short space of time. The second advantage is that the lecture method is economical in the sense that one educator can teach a large group of learners (Adams & Mabusela, 2013; Allers, 2007; Oche, 2012). Nowadays, with availability of communication systems like public address systems, the educator may teach hundreds of learners at the same time since communication is basically one way from the educator to the learners. Another advantage is that even in teaching science using the lecture method there is no need for a laboratory or large quantities of equipment and chemicals for experiments. Demonstrations can be used for teaching (Singh & Nath, 2005). This method also has an advantage that it can cover long syllabi in a short time since the educator will just be talking and the learners just listening. The lecture method assures that all prescribed content will be prepared and taught by the educator in a logical order (Adams & Mabusela, 2013; Saidi, 2004; Singh & Nath, 2005; Veer, 2004). Since the educator is the one in charge of most of the talking he/she may arrange all the topics and lecture them in a systematic order as he/she wishes (Adams & Mabusela, 2013), and this upholds discipline in the classes.

2.6.3 Shortcomings of the lecture method

Some of the limitations of the lecture method include that all assessments are controlled by the educator. The learners have no chance to assess and evaluate the extent of their learning (Oche, 2012; Poorman, 2002; Szalavitz, et al., 2004). As a result, in the lecture method it is difficult to tell how much learning has taken place. It is only easy to know how much teaching was done. Another disadvantage is that the lecture method is confined to specific sources of information, especially the educator and the prescribed text-book. Therefore, there is a lack of wide reading on the part of the learners, to acquire information from other sources (Adams & Mabusela, 2013). The content to be learned is limited since learners only use prescribed books. Another shortcoming is that the learners in a lecture method may be taught content which is out of context (Laugksch, 2000). Many examples and expressions may be abstract for learners and hence not understandable. Since they are taught from specific sources then the contexts in which the sources are based are the contexts in which learners will be taught. And since the educator does most of the talking then many learners may end up failing to understand some contexts in the text. Learners taught by the lecture method may lack a chance to discover new knowledge because they will be used to being told rather than discovering on their own. Thus the learners taught by the lecture method may lack discovery skills since they are used to get information from the educator and the prescribed textbook. The lecture approach fosters a dependency culture in the learners. The learners expect the educator to tell them everything. It is difficult for true learning to occur when learners are passive listeners (Oche, 2012; Osborne & Collins, 2001; Poorman, 2002).

The lecture method does not promote higher cognitive skills like analysis, synthesis, evaluation and critical thinking (Anderson & Krathwohl, 2000; Saidi, 2004; Singh & Nath, 2005; Veer, 2004). It appears the lecture method lacks development of metacognitive skills which include questioning, justification, and validation of arguments but focuses mainly on memorizing and recall skills (Anderson & Krathwohl, 2000; Bloom, 1956).

Researchers have suggested, among other innovations, the use of IBSE to address the shortcomings of the lecture method. For the current study, the following conceptual framework was used in order to identify the influence of IBSE compared to the lecture method on learners' understanding of the PNM in the gaseous phase.

2.7 Conceptual framework based on Posner, et al. (1982)

A conceptual framework of a study is a system of ideas, beliefs, theories, assumptions or descriptions of the main concepts, factors, procedures and their presumed relationships in the study (Earp & Ennett, 1991; Miles & Huberman, 1994; Merriam, 2009). It is an explanation of what the study is based on and may reflect the procedure the study will follow, which in the current study entails the changes to be effected by the teaching approaches and the implications the teaching approaches have on the conceptions of the learners. The framework also highlights the position of the research topic. The essential concepts in this study are learners' initial understanding, the teaching approach used, the new understanding learners have after instruction and the conceptual change process involved.

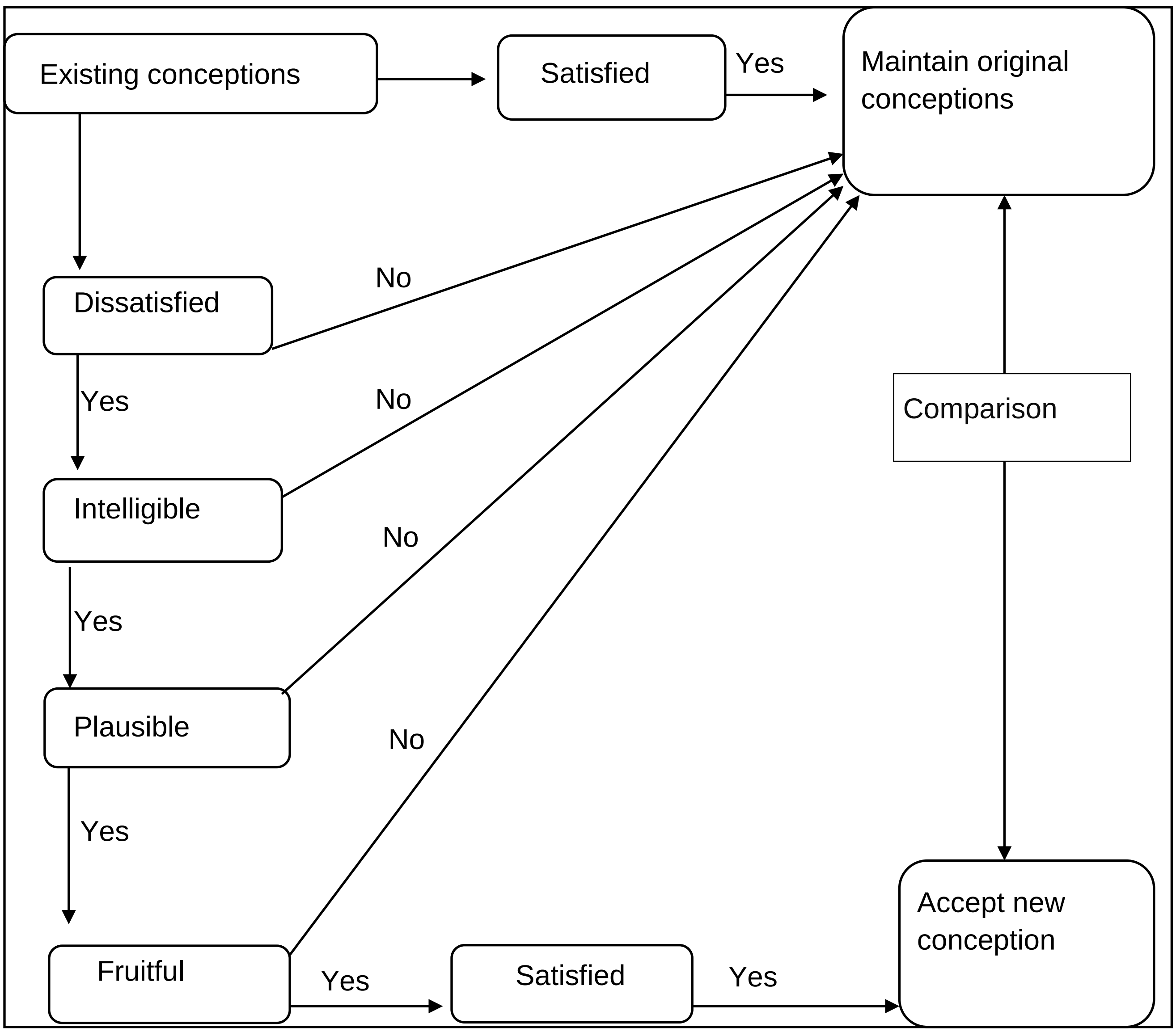
The traditional strategies of teaching start by initially proposing a new understanding to learners without inspecting their existing conception which may be incorrect or incomplete (Bybee, 2010). By using this approach, learners may not even pay attention because they may believe that they already know what they are being taught. In the conceptual change model like that studied by Posner, et al., (1982), the focus of the strategy is to initially make learners have a better understanding of their existing incorrect initial understanding. When learners see the inconsistency of their existing conception, they reach what is called a stage of "*dissatisfaction*". This dissatisfaction may encourage learners to seek alternative explanations. They will therefore pay attention to new proposals. If the new proposal is *"intelligible*", that is, if the learners make sense of its parameters, they may accept it. If not, they may restore their pre-conception. The next stage is that the intelligible conception should be *"plausible"* (Hewson, 1992; Posner, et al., 1982). This means that some parameters of this proposal should fit in well with some already existing conception. The plausible proposal should *"fruitfully"* be able to solve problems which the initial conception could not solve. If this is the case, then the new conception may replace the preconception.

The background literature review on the study of science has shown the persistence of the continuous conception of matter which hinders the future scientific study of matter.

The CCM by Posner, et al. (1982) was used in this study, as its conceptual framework. IBSE was used as one of the teaching approaches in comparison with the lecture method. The idea was to identify which of the two approaches would be able to foster better conceptual change of scientifically inconsistent ideas and enhance more scientific understanding of learners.

Figure 2. 1 Conceptual framework based on conceptual change model

(Based on Posner, et al., (1982))



This study worked on the assumption that learners have some pre-conception of matter in the gaseous phase before instruction on the topic. The pre-conceptions may consist of a mixture of correct ideas, incorrect ideas and myths. The incorrect ideas and myths may hinder effective learning of scientifically accepted concepts and processes. The diagrammatic representation of the conceptual framework for this study is as shown above in figure 2.1.

The focus is on the knowledge already possessed by learners as a starting point in effecting teaching from the known to the unknown. The assumption is that when learners properly understand their pre-conception during instruction, and if there is dissatisfaction with it, then they may change their conception for the better (Hewson, 1992; Novick & Nussbaum, 1981; Posner, et al., 1982).

Two groups took part in this study. The lecture group taught using the lecture method and the inquiry group taught using IBSE. The first stage in this study was to identify the initial understanding of learners on the topic PNM in the gaseous phase. The learners' pre-conception of matter in the gaseous phase was found to be inconsistent with the scientific view. There was need, therefore, to find a way of changing the identified initial understanding. The next stage was to use two different teaching approaches, the lecture method and the inquiry method. The assumption was that, if the teaching approach exposes the initial understanding so that it no longer satisfies the learner, the learner may seek an alternative conception to replace the existing one by replacing or reorganizing existing concepts (Posner, et al., 1982). This experience shows that the learner has recognized that the initial understanding was inadequate or wrong.

When the initial conception has seemed unsatisfactory to the expectation of the learner, the learner now seeks how the new idea is intelligible (Novick & Nussbaum, 1981; Posner et al., 1982). That is the learner wants to grasp how the new experience can be structured so as to successfully understand all its parameters. For this to occur the new concept must be plausible. A concept which is plausible would be consistent with other existing knowledge (Posner, et al., 1982). That means the learners should be able to make sense of the new idea on the basis of its link with some already inherent ideas. If the concept is plausible, then it should pass the final test of fruitfulness. That is the new concept should be able to resolve the problems which could not be solved by the initial conception. When that occurs then there is a possibility of acceptance of the new conception to replace the initial conception (Posner, et al., 1982).

The final stage was to re-assess learners' conceptual understanding post instruction. Analysis of these results was expected to provide information of learners' mental models as evidence of the occurrence of conceptual change after instruction. The comparison of the initial and final conception in the inquiry and the lecture group would show how the instructional approach influences learners' understanding.

2.8 Conclusion

This chapter is a literature review of studies conducted previously on the particulate nature of matter, learners' conceptions of matter in the solid, liquid and gaseous phases, teaching approaches for science education as well as conceptual change. This study only focused on the gaseous phase and not the other phases of matter. The aim was to explore how a teaching approach may affect learner understanding. Previous studies have revealed that learners have pre-conception on almost every topic of study (Hrepic, Zollman, & Rebello, 2010; Pringle, 2006; Szalavitz, et al., 2004). These pre-conceptions have been reported to consist of a mixture of correct and mostly incorrect ideas. The pre-existing incorrect ideas have been reported to hinder effective teaching and learning (Pringle, 2006). The pre-existing conceptions have been observed to be so strongly held by learners that it would take a well-structured teaching approach to effect a reasonable conceptual change.

Two teaching approaches were described, the IBSE and the lecture methods. The IBSE method was discussed as an example of a learner-centred approach. The basis of looking at the literature on IBSE was that it had been identified as an approach effective in developing conceptual understanding. Its advantages and shortcomings were discussed. The lecture method, regardless of its shortcomings, remains the most commonly used teaching approach at school level due to its advantages discussed in this chapter. The conceptual framework guiding the study was described. The conceptual change model was deemed appropriate as a guiding theoretical framework for the current study.

CHAPTER 3: RESEARCH METHODOLOGY

3.0 Introduction

This chapter is a discussion of the research paradigm, methodology and data collection processes. The pilot study conducted for the purposes of establishing trustworthiness, credibility and dependability of the data collection instruments will also be discussed in this chapter. A detailed description of the lessons used in teaching, the IBSE and the lecture methods are also included in this chapter.

3.1 Paradigms

A paradigm is a set of basic beliefs or worldviews which guide the investigation. Paradigms also guide the choices of methods and the ontological and epistemological fundamentals (Guba & Lincoln, 1994; Nieuwenhuis, 2011). To date the existing paradigms are positivism, post-positivism, critical theory and interpretivism (Guba & Lincoln, 1994; Nieuwenhuis, 2011; Scotland, 2012).

Positivism is a belief that assumes a 'real' reality which can be apprehended. If believes that a reality is governed by natural laws and mechanisms and these lead to 'knowledge' of the 'real' reality-of the way things really are. Post positivism believes in critical realism. That reality is believed to exist but can be imperfectly apprehended due to the imperfections of human intellectual mechanisms. Critical theory assumes that reality can be apprehended but has been transformed over time because of social, political, cultural, or economic factors (Guba & Lincoln, 1994; Goldkuhl, 2012; Nieuwenhuis, 2011).

The paradigm guiding this study is interpretivism. Interpretivism is the basic paradigm for qualitative research from which critical theory and constructivism paradigms branched (Nieuwenhuis, 2011). An interpretivist researcher assumes a reality which consists of people's subjective experiences of the external world. This study is based on the relativist ontological view that knowledge is socially and experientially constructed (social constructivism) (Goldkuhl, 2012; Nieuwenhuis, 2011). I am of the view that learners' ideas are better captured and understood by observing them in a natural classroom context (Bybee, 2010). I am of the opinion that learners may modify their behaviour by trying to impress the educator or peers, if they are not observed in natural context.

The purpose of my study was to analyse and interpret learners' responses to various questions so as to try and construct meaning about the conceptual understanding learners have on the topic of matter in the gaseous phase. There is no correct or incorrect answer in the responses learners give but a series of multiple realities (Cantrell, 2001; Guba & Lincoln, 1994; Nieuwenhuis, 2011). Interpretivism seeks to understand the world as it is subjectively viewed by different individuals (Cantrell, 2001). This paradigm is underpinned by observation and interpretation. Thus for this study learners' responses were analysed and interpreted in relation to observations made in previous studies. This study is underpinned by the transactional subjectivist epistemology. Truth is negotiated through dialogue. Thus findings emerged as the investigation proceeded (Cantrell, 2001; Guba & Lincoln, 1994; Nieuwenhuis, 2011).

The methodological paradigm of this study is qualitative because it appeals to me as the best way to establish some understanding. The methodology for this study is based on observations, interviews and analysis of learners' responses. These methods allowed adequate dialogue with the learners in order to construct meaningful reality of the learners' understanding. The aim was to get understanding of learners' conceptual understanding by analysing and interpreting learners' responses in the form of drawings, spoken words in interviews, expressions and actions observed during the lessons and in the interviews. Therefore, qualitative methods were deemed most appropriate.

The following table summarizes the characteristics of the interpretivist paradigm and how it relates to this study in terms of the purpose and nature of reality, the nature of knowledge and the relationship between the inquirer and the inquired.

Table 3. 1 Characteristics of interpretivism in relation to this study

Feature	Description
Purpose of this study	To explore the influence of IBSE as compared to the lecture method in promoting grade 4 learners' understanding of the particulate nature of matter in the gaseous phase.
Ontology (nature of reality)	There are multiple realities. Careful analysis and interpretation of learners' responses can provide the researcher with a glimpse of multiple realities of learners' conceptual understanding. Reality can be constructed when humans interact. Learners' responses in tests are indicative of their conceptual understanding. There is an accepted scientific model, the particulate model, against which learners' views of reality are evaluated.
Epistemology	Interpretation of learners' drawings and discussion with them may lead to understanding of their mental processes. Learners' drawings can be meaningfully interpreted by using a theoretically informed framework.
Methodology	Qualitative data is best collected and analysed by using interviews, observation and thematic analysis respectively.

3.2 Research Approach

This research followed a qualitative approach where an in-depth study was undertaken of the learners' understanding of matter in the gaseous phase. Qualitative data constituted learner responses in the form of drawings, explanations of learners in the group interviews, lesson observation field notes as well as responses of educators.

A research design is a plan based on the underlying philosophical assumptions to specific actions on the research. The actions include selection of participants, design of appropriate instruments, the application of instruments, collection of data and how data shall be analysed (Nieuwenhuis, 2011).

The research design for this study was a case study. A case study is a design in which a particular scenario is studied without the intention to generalize the findings (Ebersohn, Eloff, & Ferreira, 2011). This study examined the influence of inquiry-based teaching and the lecture method on learners' understanding of a topic in grade 4 Natural Sciences and Technology, the particulate nature of matter in the gaseous phase. Rich data were collected from four grade 4 classes using the pre-test, post-test, follow up test, interviews and observations. An advantage of case study research is that the approach advocates for observation of participants in their real-life situation, thus already existing grade 4 classes were observed in natural classroom settings in the presence of their class educators.

Although this is a qualitative study the quasi-experimental pre-test post-test design was followed to obtain qualitative data from which conceptual change could be inferred. Quasi-experimental research does not allow randomization. As a result, the findings may not be generalized because of the small sample used (Maree & Pietersen, 2011). The elements of experimental methodology are evident in the comparison of findings from IBSE and the lecture method.

3.3 Sample

The sample was made up of four grade 4 classes. Two classes were from each of the selected two schools. At each school one of the two classes was labelled as the lecture class and the other class was labelled as the inquiry class. But the learners in all the classes were not told about the labels given to their respective classes. All classes were initially given a pre-test to assess their prior knowledge followed by the first group interviews on five learners per class. All learners were taught by two experienced educators. After instruction a post-test was administered to all classes followed by the second group interview composed of five learners per class. The number of learners who gave consent to participate in the study is shown in the table 3.2 below.

Table 3. 2 Table showing the number of participants in the study

	Inquiry group			**Lecture group**		
	School A	School B	Totals	School A	School B	Totals
Total in class	24	45	**69**	26	45	**71**
Gave consent	22	37	**59**	23	34	**57**
Total participants	**22**	**37**	**59**	**23**	**34**	**57**

A total of 59 learners participated in the inquiry group and 57 learners participated in the lecture group. Therefore, a total of 116 participated in the study. The number of learners for whom consent for participation was not granted was 24. Their educators collected their pre-test and post-test scripts which were therefore not used in the data analysis. The reason for the participation of such learners in the tests and their presence during the lessons was because the content of the lessons was part of their syllabus and leaving the learners out would have disadvantaged them. So they took part in all the class activities like other learners, including writing the pre-test and the post-test. These learners did not participate in the group interviews and their scripts were not used during data analysis.

3.3.1 Sampling procedure

The following paragraphs shall elaborate the sampling procedure for the schools, educators, classes and the learners who participated in the study.

3.3.1.1 Sampling procedure for schools

The sampling procedure was purposeful and convenience sampling. It was purposeful in that Natural Sciences and Technology is first taught in grade 4 in South Africa. So in this study the focus was on grade 4 to avoid any influence of rote learning in the subject which could have affected the study (Areepattamannil, 2012). Sampling of schools was convenient in that the experienced educators who taught the intervention were full-time university teacher educators. They had limited time to spend away from the university so schools close to each other and close to the university conveniently suited them. It was therefore important to make arrangements of suitable times for the researcher, the experienced educators and the schools concerned.

Field notes and test scripts constituted qualitative data collected during school hours. Interviews with school educators were conducted after normal school working hours. The sample was convenient to the availability of the researcher, the experienced educators and the educators at the sample schools. This allowed the research to be feasible since many people were involved in the study. The participating schools were primary schools with at least two grade 4 classes.

3.3.1.2 Sampling procedure for classes

Two already existing grade 4 classes at each school were conveniently selected. The two selected classes were those of the educators who had agreed to take part in the study. Grade 4 learners were chosen to participate in this research because these learners are in their early stages of learning science. They are at the stage of starting to learn the basics of science. As a result, teaching them science by inquiry may help the learners to understand science better. The decision to use grade 4 learners was also on the basis that too much exposure to the traditional teaching approach has a negative impact on IBSE (Areepattamannil, 2012).

3.3.1.3 Sampling procedure for grade 4 educators

The grade 4 educators who participated in the research were conveniently sampled on the basis of their willingness to participate in the research. The selection criteria were as follows: educators with at least five years of experience teaching grade 4 after qualifying as educators with at least a diploma from a recognized educator training institution. The assumption was that such educators may have had enough experience working at the same grade and may have tried to use different teaching approaches during their teaching of Natural Science over the years. As a result, they may have some interest in finding an approach that may foster improved understanding or performance of their learners.

How the educators were sampled was as follows: When I got permission from the principal of school A, I was allowed to meet the only two grade 4 educators in the school. Both of them had enough experience and qualifications, and agreed to participate in the study. At school B there were four grade 4 classes all of whom had the required experience and qualifications. I asked the first two and they agreed to participate and then I never spoke to the other educators because the two willing educators met the criteria I stated above.

The educators whose classes were taught using IBSE as part of the intervention were expected to observe the inquiry lessons and give feedback during interviews. They were interviewed on how they perceived the teaching approach used in the inquiry lesson as well as how this influenced learner participation.

3.3.1.4 The experienced educators

Two teacher-educators experienced in both inquiry and lecture methods helped in the intervention. The experienced educators were university lecturers who specialized in teacher education. They had experience in training educators to teach Science at the intermediate and senior levels. Although university lecturers, the two experienced educators prepared and presented the lessons to the level of grade 4 learners. To reduce tension that could have been caused by the learners being taught by complete strangers, the class teachers of participating learners were asked to be present during the lessons.

At school A experienced educator 1 taught using IBSE and experienced educator 2 taught using the lecture method. At school B experienced educator 1 taught using the lecture method and experienced educator 2 taught using the IBSE method. In other words, each experienced educator taught in one school using the lecture method and taught in the second school using the IBSE method. Only two classes participated per school so one was the inquiry class and the other was the lecture class. Each class was taught by one of the experienced educators for two hours.

The use of both teaching approaches by both experienced educators helped to reduce the bias due to subjectivity towards a specific teaching approach. Table 3.3 below depicts the teaching approach followed by each educator in each school.

Table 3. 3 Class allocations for experienced educators and teaching approaches in each class

Experienced educators	**Classes taught**	**Schools**
Educator 1	Inquiry class A	**School A**
	Lecture class A	
Educator 2	Inquiry class B	**School B**
	Lecture class B	

3.3.1.5 Number of participants for the current study

Qualitative data was obtained using the instruments of data collection described in above. All the scripts for both the pre-test and post-test were scanned and loaded onto *Atlas.ti* version 7 for qualitative analysis. Scripts analysed included 59 scripts for the pre-test for the inquiry group and 57 for the lecture group giving a total of 116 pre-test scripts. After the pre-test four first group interviews were conducted. Each group consisted of five participants. The first group interviews for the four classes were recorded, transcribed and also loaded into *Atlas.ti* version 7 for qualitative analysis. In the post-test, the inquiry group had 54 participants and the lecture group had 47 participants. Their scripts were also scanned and loaded into *Atlas.ti* version 7 for qualitative analysis. Once again four groups of five learners each participated in the second round of group interviews followed by recording, transcribing and loading into *Atlas.ti* version 7. Two educators for the inquiry group were interviewed, which was as well recorded and transcribed and loaded into recorded, transcribed and also loaded into *Atlas.ti* version 7. The follow up test was taken by 55 participants in the inquiry group and 52 participants in the lecture group. In Table 3.4 below is a detailed summary of the number of participants for this study.

Table 3. 4 Table showing number of participants for this study

Data collection procedure (for schools A & B)	**Number of classes**	**Number of participants**	**Total number of participants**
Pre-test inquiry group	2	59	116 learners
Pre-test lecture group	2	57	
First group interview	4 groups	5 x 4	20 learners
Post-test inquiry group	2	54	
Post-test lecture group	2	47	101 learners
Second group interview	4 groups	5 x 4	20 learners
Interview for educators	2 educators	2 x 1	2 educators
Follow up test inquiry group	2	55	
Follow up test lecture group	2	52	107 learners

All the eight group interviews, as well as the interviews for the two inquiry class educators, were initially transcribed and also loaded onto the same software. Much detail on this is in section 3.5.1 under thematic analysis.

3.4 Data collection plan

3.4.1 Overview of the data collection procedure

Participants were from two primary schools. At each school two grade 4 classes were identified. One of the classes at each school was labelled the inquiry class, and the other was the lecture class. The classes were assigned to these teaching methods by random selection by the researcher. The total number of participating classes was four.

All the four grade 4 classes were initially given the same pre-test (appendix I) to determine the learners' initial understanding of the topic of matter in the gaseous phase. After the pre-test in each class five learners were randomly selected to participate in the initial group interview. During the interview, the learners gave explanations on their drawings in the pre-test. The results from the pre-test and the initial focus group interview gave answers to the first research question, which sought the initial understanding of the learners before instruction.

On another day the inquiry class in each school was taught using the IBSE method, and at the same time, the lecture class was taught using the lecture method. The teaching lasted two hours per class and was administered by experienced educators using lesson plans (appendix IX and X) designed by adapting Bybee's 5Es model Bybee (1997), for the inquiry group and for the lecture group. Activities of both learners and educators in both the inquiry and the lecture group are indicated in the lesson plans. This was the intervention.

On the same day after the teaching, each class was given a post-test (appendix VII) followed by the final group interviews. The results from the post-test and the final group interviews answered the second research question, which sought the understanding of learners after intervention. On another day the grade 4 educators of the inquiry group were separately interviewed in their classes after the final group interviews for the learners.

All interviews (four initial group interviews, four final group interviews and two interviews for educators) were transcribed. The ten interview transcriptions and all the pre-test and post-tests written by the learners were loaded into *Atlas.ti* version 7 software package for coding and categorizing. The results from coding and categorizing were analysed. The preliminary analysis led to the need to prepare a follow up multiple choice test similar to the post-test. The follow up test was recommended by the research supervisors so as to determine the trustworthiness of the findings. The responses of the learners were used as multiple choice distractors in the follow up test. The results for this study will be presented and discussed in the paragraphs that follow.

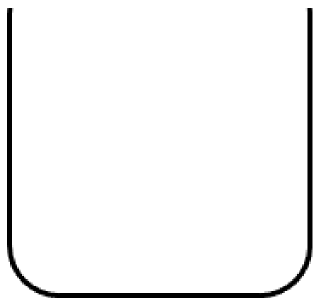
3.4.2 Description of the data collection instruments

The test instruments used in this research were adapted from suitable already existing items which had been tested and proven valid for use in the topic particulate nature of matter. The researcher adapted the work done by Novick and Nussbaum (1981) on the particulate nature in the gaseous phase. The tests, pre-test (appendix I) and post-test (appendix VII) were comprised of items of moderate level of difficulty assessing for conceptual understanding. The same items used in the pre- and post-test were used in the follow-up test. Only this time samples of learners' responses were incorporated as distractors. This has been indicated in section 3.4.1. All the items required learners to provide responses in the form of drawings assuming they wore magic glasses which enabled them to see air.

3.4.2.1 Pre-test and post-test instruments

The pre-test (appendix I) consisted of five questions. The first question showed an empty beaker. Learners were asked to draw air inside it.

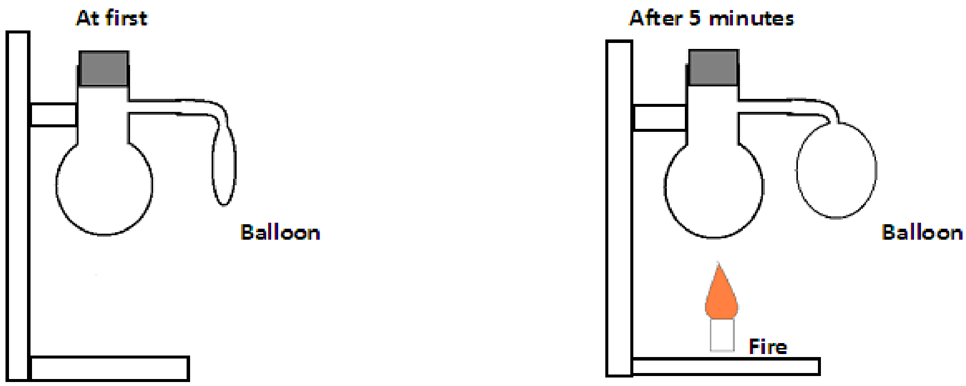
Figure 3. 1 Pre-test diagram for item one



The aim was to expore learners' understanding of how air looks in an open container. The expectation here, consistent with the literature, Novick & Nussbaum (1981), was that learners would either shade the whole beaker, shade the upper part only or shade the bottom only based on the findings presented in table 2.1. These are the various continuous models as revealed in previous studies (Novick & Nussbaum, 1981). The learners could also have made dots or circles with spaces in between showing the particulate model. The idea of space between dots or circles would show that learners consider the existence of a vacuum (Novick & Nussbaum, 1981).

The second question consisted of two drawings. The first drawing was a flask clamped to a stand with a balloon tied on its lateral tube before heating. The second drawing was the same setup but with a burner at the bottom and this time the balloon was shown already inflated with air as depicted in figure 3.2 below.

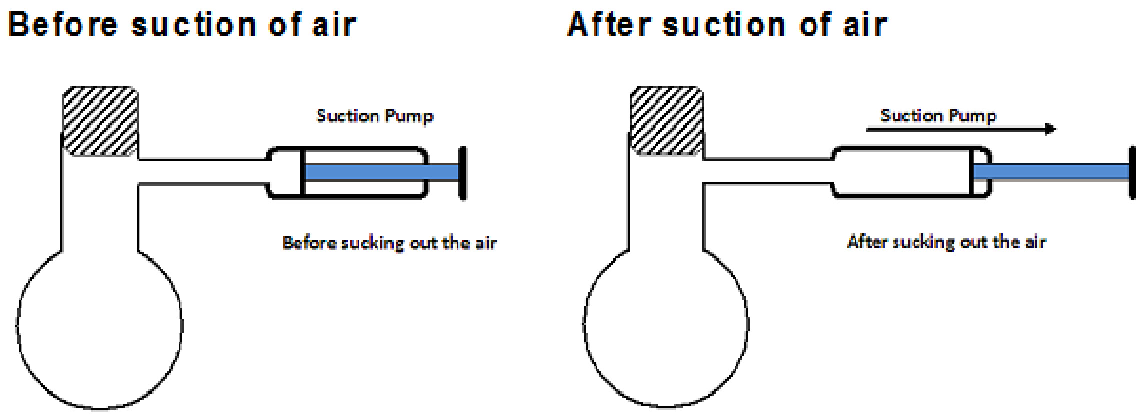
Figure 3. 2 Pre-test diagram for item two



The learners were supposed to draw air in both flasks and balloon before and after heating. The first drawing assessed learners' understanding of nature of matter in the gaseous phase in a closed container. The second drawing sought learners' understanding of matter in the gaseous phase when the flask is heated and the balloon had been inflated. A previous study had revealed that leaners would draw air whether by dots or shading, away from fire indicating animistic behaviour that the particles are running away from heat. Some learners may have drawn more air in the second drawing showing that they may be thinking that some air is coming from the fire source (Novick & Nussbaum, 1981).

The third question consisted of two drawings. The first was a closed flask with a suction pump attached on its lateral tube with the pump not drawn out. The second drawing was similar but the pump was now pulled out as shown in figure 3.3 below.

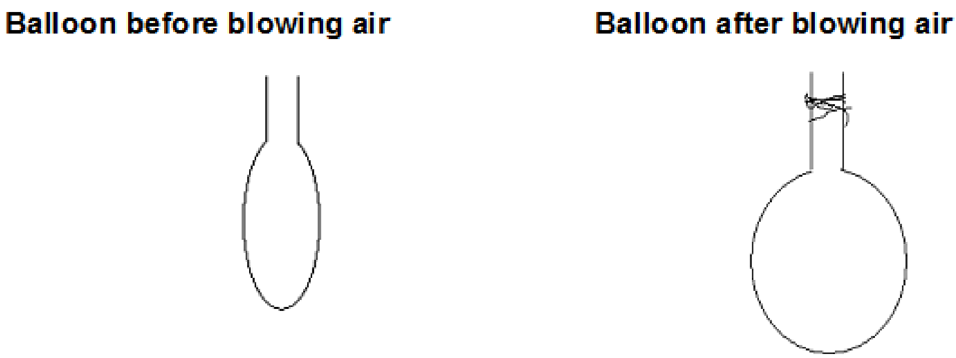
Figure 3. 3 Pre-test diagram for item three



The first drawing sought learners' understanding of the particulate nature of matter in the gaseous phase in a closed container. It sought the ideas of space between particles, particulate, or continuous models including the animistic and the empty conceptions. The second drawing sought the conception of learners on the arrangement of particles after volume was increased by pulling out the suction pump. The question was looking for an increase in the size of vacuum between particles but the particles still being evenly distributed. In the second drawing the learners could also have drawn air in the pump leaving a vacuum at the bottom assuming continuous conception. Another variation would have been a gap of vacuum somewhere between the bottom of the flask and the pump. These would have shown a continuous empty model.

The fourth question had two drawings of a deflated balloon in the first and an inflated balloon in the second drawing as shown in figure 3.4 below.

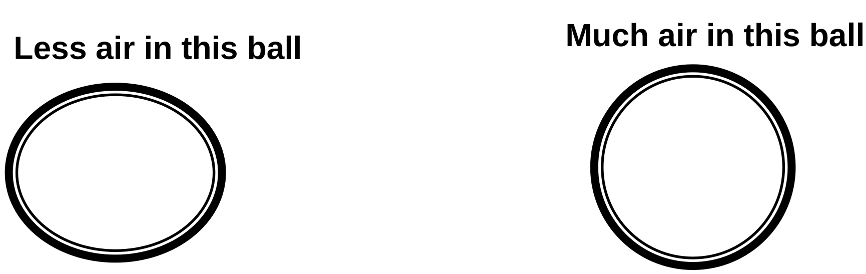
Figure 3. 4 Pre-test diagram for item four



The aim was for learners to show their understanding of air in the two drawings. In the first the learners were supposed to show if they expected the balloon to be empty, i.e. a vacuum or to have a little air. It also sought to establish if the learners' conception would be that of particulate, continuous or animistic behaviours. The second drawing sought the learners' idea of the arrangement of air in an inflated balloon, i.e. whether learners would draw more air in the second balloon than the first or the same amount, and whether the learners would evenly distribute air in the inflated balloon or confine air to the walls or the centre, showing animistic conception.

The fifth question had two balls, the first one with little air and the second with much of air as shown in figure 3.5 below.

Figure 3. 5 Pre-test diagram for item five



Learners were supposed to draw air in both balls. The first sought the understanding of learners on particulate arrangement in a ball with less air, i.e. whether learners would draw air at the bottom only showing the animistic idea of resting air, or whether they would draw air evenly distributed in the ball showing they do not have an animistic idea. In the second ball learners were expected to have drawn air distributed evenly. They would have shown that there was more air by either shading darker or by more dots or circles. Learners could have drawn air in the second ball only confined to the walls of the ball or the centre showing a continuous empty model. The following table 3.5 is a summary of the description of the items in the pre-test on what they intended to assess.

Table 3. 5 The pre-test items and corresponding assessment outcomes

(More detail is in appendix I)

Item	**Description of question**	**Aim of the question:** **For learners to demonstrate their understanding of the arrangement of air**
1	Empty beaker	-in an empty open container.
2	Empty flask with balloon without burner and one with lit burner underneath	-in an empty flask and balloon and arrangement of air in the same setup when heat is introduced.
3	Flask with syringe before suction and after suction.	-in a flask and attached suction pump before and after suction.
4	Deflated and inflated balloons	-in a balloon before and after inflation.
5	Ball with less air and ball with much air	-in a ball with less air and in a ball with much air.

Similarly, learners were required to complete the post-test (appendix VII) by making drawings. Learners were tested on the same criteria as in the pre-test described above. The post-test was contextually like the pre-test with minor changes and additions. The first question of the post-test was like the first question of the pre-test. The difference was that instead of an empty beaker, the post-test had an empty flask. The second question in the post-test was like the fifth question in the pre-test. The slight difference was that the pre-test had a ball with less air while in the post-test the ball had a puncture. In principle both first balls had less air than the second ball. The third question in the post-test was similar to the second question in the pre-test. The slight difference was that in the pre-test the flasks were empty while in the post-test the flasks had a little water in them. The fourth question in the post-test was exactly the same as question three of the pre-test. The fifth question in the post-test was exactly the same as question four of the pre-test. The slight difference was that the first drawing of the balloon was rotated through ninety degrees.

Table 3.6 below gives a descriptive overview of the items included in the post-test with corresponding assessment outcomes. More detail is in appendix VII.

Table 3. 6 The post-test items and corresponding assessment outcomes

Question	**Description of question**	**Aim of the question:** **For learners to demonstrate their understanding of the arrangement of air**
1	Empty round-bottom flask	-in an empty open container.
2	Ball with a puncture and ball without a puncture	-in a ball with less air and in a ball with much air.
3	Empty flask with balloon without burner and with lit burner underneath	-in an empty flask and balloon and arrangement of air in the same setup when heat is introduced.
4	Flask with syringe before suction and after suction.	-in a flask and attached suction pump before and after suction.
5	Deflated and inflated balloons.	-in a balloon before and after inflation.

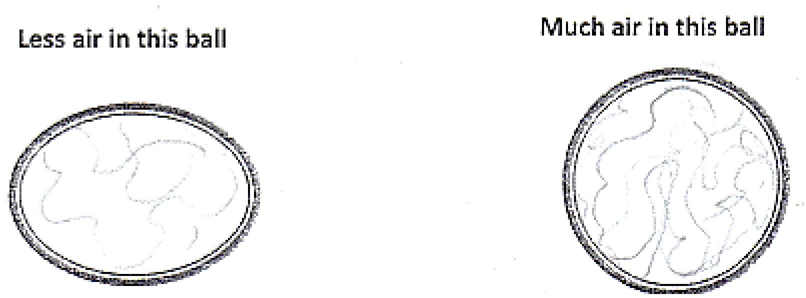
3.4.2.2 Group interviews for learners

The schedule used for group interviews (appendix II) comprised of open-ended questions that were formulated with the aim of eliciting learner conceptual understanding. The interview schedule was semi-structured to allow the researcher to probe even further when necessary. The questions were dependent on the drawings the learners in the group had drawn. Each learner in a group of five was asked about their drawing in the first question before moving to the second question. As such all learners were focused on the same question standing around a table with their scripts on the table. The researcher asked all the learners one by one about their response to the same question. The following section is an example of how learners were asked in the interview.

Figure 3. 6 Examples of probing questions based on learners' drawings.

Question 5

Two identical soccer balls **one with a lot of air pumped in** and another **with less air pumped in** are shown below. If you have magic glasses which can allow you to see air, draw the air that is inside each ball.



For the drawings such as shown in figure 3.6 above, the follow up questions would specifically refer to strings representing the gas, as outlined below:

Question: **What did you draw inside the balls?** (This question prompts the learner to describe what he or she has drawn. The expected answer would be that this is air.)

Follow-up question 1: **Why did you draw air like this?** (This question asks the learner to justify his or her representation of air. A learner would respond that this is how air looks like when viewing it through the magic glasses.)

Follow-up question 2: **Does air look like strings like that?** (This question prompts a learner to elaborate further in his or her justification given in follow-up question 1. The learner would respond that yes air looks like strings. This shows that the learner believes air looks like strings.)

Follow-up question 3: **Why did you draw many strings in the second ball and few strings in the first ball?** (This question prompts the learner to explain the difference in representation as indicated in his or her drawings in the first and second balls. The learner would respond that the second ball has much air and the first has less air. This shows that the learner is aware of density of air.)

Follow-up question 4: **So when we have much air we draw using more strings?** (This question tries to establish conceptual understanding behind the representation. The learner would agree.)

Follow-up question 5: Why did you draw with long strings like this which do not end? (This questions prompts the learner to explain his or her choice of representation. The learner would respond that air is like that, it does not end. This shows an idea of continuous conception.)

Follow-up question 6: In the first drawing there is space which is blank between the strings but in the second that space is small. What is in that space? (This question assesses the learner's conception of vacuum. Learners would respond that the space is empty showing continuous empty. They may also say that there is air or dust in the space showing the continuous model.)

3.4.3 Trustworthiness

Trustworthiness involves the establishment of credibility, transferability, dependability and confirmability of a research study (Guba & Lincoln, 1985). This is the establishment of how a researcher may be able to persuade the audience and self that the findings are worth taking note of. The trustworthiness of a study demonstrates the truth value of a study, the basis of how it can be applied and the consistence of its procedures and how neutral its findings and decisions are. This study only focused on the gaseous phase, unlike the study by Novick & Nussbaum (1981) which looked at the three phases of solid, liquid and gas. The elements of trustworthiness of this study are discussed in the following paragraphs.

3.4.3.1 Credibility

According to Lincoln and Guba (1985) credibility of a study is the confidence in the truth delivered on the intended findings. In this study the pre-test and post-test items were adapted from test items reported to have been used in related research by Novick & Nussbaum (1981). Items used have been reported to have been successfully used for many years in many countries. Making use of such items was a measure taken to ensure that the test instrument used measured what they were intended to measure. In this study four grade 4 educators and two university lecturers evaluated the test instruments prior to use to ascertain the extent to which they would enable credible data collection. They provided feedback on the ability of the instrument in assessing the understanding of learners through the drawings they make. The instrument was, therefore, deemed trustworthy for the intended use (Nieuwenhuis, 2011).

Another strategy that a researcher can use to increase the credibility of his or her findings is triangulation. Triangulation is the use of either multiple instruments to collect data, or using multiple analysts in data analysis so as to compare and validate findings. Triangulation helps to get a deeper understanding of the phenomenon under investigation (Shenton, 2004). In this study multiple methods of data collection were used. These were the pre- and post-test, group interviews, classroom observations as well as educator interviews. These methods of data collection were used collectively with the aim of establishing the mental models or constructions of learners of matter in the gaseous phase.

3.4.3.2 Consistency

Consistency is another measure taken to increase trustworthiness of the research findings. It refers to the extent to which research findings can be duplicated (Shenton, 2004). The instrument adapted for this study was successfully used previously and also on primary school children. The way the instrument produced acceptable results of learners' mental models in the past is the same way it provided information in this study. The pre-test and post-test were adapted from Novick and Nussbaum (1981) whose test instrument succeeded in revealing learners' mental models. A pilot study was done using a grade five class at the researcher's workplace. This helped to test the dependability and hence the trustworthiness of the test instrument.

3.4.3.3 Dependability of the data collection instruments

Dependability has to do with whether the results of a study are consistent with the data collected (Lincoln & Guba, 1985). This measure can be increased by investigator triangulation. All written work for the pre-test and post-test was loaded into *Atlas.ti* version 7 for qualitative data analysis coding and categorizing. One of my supervisors also loaded some of the scripts into *Atlas.ti* version 7 and coded and categorized them. A discussion took place with the researcher on how the researcher had coded in comparison with how the supervisor had coded. This provided investigator triangulation (Patton, 2002) by providing credible and multiple ways of observing data. This increased the credibility of the coding scheme and the process used, reducing primary investigator bias.

3.4.4 Data collection procedure

The process for data collection is as shown in table 3.7 below;

Table 3. 7 Sequence followed for data collection

Data collection method	Participants	Aim for data collection
1. Pre-test	All four classes	To get initial understanding of learners.
2. First group interview	Five learners in each of the four classes	To get deeper information on and clarity of learners' initial understanding as depicted in their answers in the form of drawings.
3. Intervention	Inquiry class: 1 class at each school using inquiry method	To effect conceptual change using inquiry method.
	Lecture class: 1 class at each school using the lecture method	To effect conceptual change using the lecture method.
4. Post-test	All the four classes	To get the understanding of learners after instruction.
5. Second group interview	Five learners in each of the four classes	To get deeper information on and clarity of learners' new understanding.
6. Follow up test	All the four classes	To get the understanding of learners some months after instruction. Testing retention of understanding. Testing for consistency of the data collection instrument used.

In this quasi-experimental pre-test post-test method, four already existing grade 4 classes, two from each school, participated in the study. A pre-test was administered to all classes. The results were analysed to determine the initial understanding of learners in all the classes about the particulate nature of matter in the gaseous phase.

Considering the age of the learners involved in the study and also previous research by Novick and Nussbaum (1978), the researcher read each question to the learners and explained the meaning of each question to ensure that they understood the questions clearly. The researcher used suitable and familiar apparatus to demonstrate the questions so as to allow the learners to see and understand the question.

All the scripts of learners in both the pre-test and post-test and the interview transcriptions for both learners and educators were all scanned and loaded into *Atlas.ti* version 7, a software for qualitative data analysis. All the drawings and learners' expressions in interviews were coded and classified into relevant themes showing learners' conceptions of matter in the gaseous phase before and after instruction.

3.4.4.1 Intervention

The inquiry group was taught using the IBSE approach while the lecture group was taught using the lecture method. The experienced educators taught both the inquiry group and the lecture group following the teaching approach guidelines based on Bybee's 5Es instructional model. Bybee's (2011) frameworks stipulate the activities of both the educator and the learners for both teaching approaches. This served as a guide and checklist for the lesson activities of both educators and learners in both the inquiry-based science education and the lecture method. The possible biases were minimized by using this checklist.

A brief summary of the lessons is as shown in table 3.8 below. In this table the aim of the lesson and the major apparatus used are shown. The inquiry lessons consisted of two tasks each where learners were exposed to some inquiry activities and worked through hands on activities to answer specific questions. More detailed lesson plans have been included as appendix IX but below is a summary of the lesson plans and the activities involved. The main apparatus used in each activity is also shown.

Table 3. 8 Summary of inquiry lesson plans used in the study

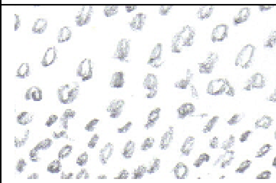
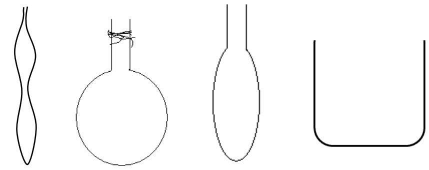
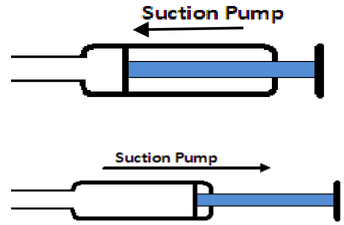
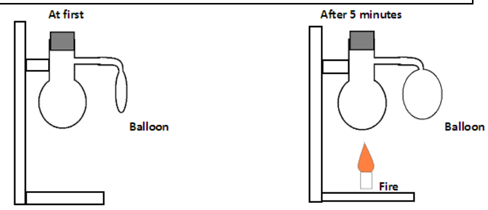
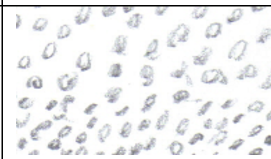
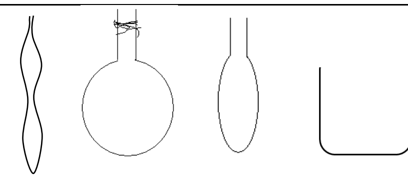
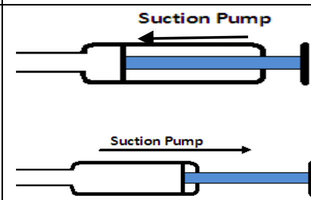
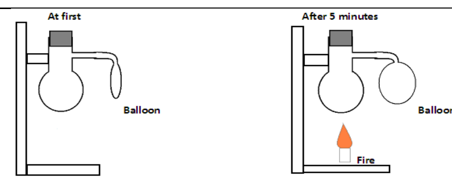
Lesson/ Task	**Activity**	**Demonstration and apparatus used**
Lesson 1 Task 1	Prompting learners to predict how air would look as seen using magic glasses using movement of perfume particles in a classroom from one place to another as an example.	
Lesson 1 Task 2	Educator prompts learners to draw how air in a beaker and different shaped balloons looks like. Blowing balloons and stating shape of air inside the balloons. How air is distributed in the balloons and beaker.	
Lesson 2 Task 1	Learners compressing air in a syringe and pumping out air from a syringe with mouth of syringe closed. Drawing air in the syringe and particulate arrangement. Explain what happens to particulate arrangement when pumping in and when pumping out.	
Lesson 2 Task 2	Learners observing a practical and predicting gaseous arrangement. Using the shown apparatus learners draw air before and after heating. Learners explain particulate arrangement before and after heating. Explain what causes the balloon to enlarge when flask is heated.	

Table 3.9 below is a summary of the activities used in the lecture lessons. The full details of the lesson plans can be found in appendix X.

The lecture lessons and the inquiry lessons have the same aim but different approaches resulted in different activities. In the inquiry lessons learners were given a lot of materials to work with in various activities to determine answers to the question about matter in the gaseous phase. The learners in the inquiry lessons made use of their observations to come up with reasonable drawings of air in different situations. In the lecture lessons learners did not do any activities. They were told and given all the notes and all the necessary drawings.

Table 3. 9 Summary of activities in the lecture lesson

Lesson/ Task	**Activity**	**Demonstration and apparatus used**
Lesson 1 Task 1	Learners are taught the drawings of air as seen using magic glasses. Educator draws the structure of air on the board and learners copy the diagram in their books.	
Lesson 1 Task 2	Educator draws different shaped objects on the board and then draws air inside the containers. Learners are asked to copy the drawings in their books. Educator explains that air fills the whole container.	
Lesson 2 Task 1	Educator draws and explains how air looks like in a compressed syringe and an expanded syringe. Learners copy the diagrams given by the educator.	
Lesson 2 Task 2	Educator makes the drawings on the board and explains to the learners how air will be arranged before heating and after heating. Learners copy the drawings and notes given by the educator.	

The researcher and the grade 4 educators observed each IBSE lesson. The researcher then interviewed the two grade 4 educators separately, on their observations of the IBSE lessons in comparison to their usual teaching methods. The educators provided rich data about how they observed the learning patterns of their learners during each teaching approach and also had suggestions about some stages during each teaching approach. All this helped to provide an educator's perspective on what should constitute a teaching approach which fosters improved understanding of abstract and difficult science topics.

After the intervention a post-test was administered to both groups. A second group interview was conducted with the learners to give them an opportunity to explain their drawings after each teaching approach. The participants in the second group interviews were randomly selected and were not necessarily the ones who participated in the first group interviews. The results of both the pre-test and the first group interviews were used together to find the initial understanding of the learners. On the other hand, the results of the post-test and the second group interviews were used together to determine the learners' understanding after instruction. The educators of the inquiry group also observed the lessons and were later interviewed. The interview sought the opinion of educators as they observed the IBSE lessons to give an input into the activities done in the class to get their feelings about the behaviour of learners, the effectiveness of the teaching approach and its comparison to the way they normally teach.

According to Schwandt (2007), field notes are evidence on which inquirers base their claims about understanding obtained during a study. These are notes made during class observations as learners did their activities and also during test-taking. The field notes for this study were based on some of the work done by learners during the lessons and most importantly as they completed their test scripts during the pre-test and post-test as well as during the interviews. The field notes were on the different expressions and reactions of learners as they discussed in their groups and the ideas they shared and finally the ideas they agreed to use as a group. It also included the justifications the learners gave for each of their ideas. Some four months after the post-test a follow-up test was given to the learners. This test was there to test the consistency of the test instrument and whether the results obtained were dependable.

3.5 Data analysis

In the following paragraphs is a discussion on how the data collected was analysed to answer the research questions.

Sub-research question 1: What initial understanding do grade 4 learners demonstrate on the topic PNM in the gaseous phase?

This question sought to find the initial understanding of learners of the particulate nature of matter in the gaseous phase before being exposed to formal education on the topic. Learner responses to the pre-test were scanned and the first group interviews transcribed and these were loaded into *Atlas.ti* version 7 for coding and categorizing. The data was analysed in an attempt to determine the initial understanding of learners on the topic as demonstrated by their drawings which were a depiction of gaseous particles in different scenarios. Five learners participated in each group interview. Each question in the pre-test focused on some specific properties of the particulate nature of matter in the gaseous phase as listed Table 3.10 in section 3.5.1 below.
The results from the pre-test gave the researcher an indication of the initial understanding of learners and served as a guide on how the lessons had to be presented. The pre-test was administered to both the inquiry and the lecture group at both schools A and B.

Sub-research question 2: What level of understanding do learners in the inquiry and lecture groups have after being taught with IBSE and lecture methods respectively?

This research question sought to find the understanding of learners after the intervention which entailed the inquiry-based teaching approach for the inquiry group and the lecture method for the lecture group. A post-test was used to obtain data to answer this research question. The post-test was made up of a set of questions similar to the pre-test but asked in slightly different contexts. Learners responded in the post-test, again using drawings. Second group interviews were conducted with five learners from each class. The interviews sought a deeper insight into the understanding of learners as indicated in their drawings. The field notes also helped to enrich our knowledge of learners' understanding of matter in the gaseous phase during instruction, and to get information about conceptual change that might have or have not occurred. The interview for educators also provided information about the educators' assessment of the understanding of the learners.

3.5.1 Thematic analysis

Thematic analysis is the method of identifying, analysing, and reporting patterns in the data (Braun & Clarke, 2006; Kirschner, Sweller, & Clark, 2006). Thematic analysis reveals how the researcher analysed data and on what assumptions they based their analysis. This study used a combination of deductive and inductive thematic analysis. In the inductive approach themes are allowed to emerge from the data (Fereday & Muir-Cochrane, 2006; Patton, 2002). This study was based on the study by Novick and Nussbaum (1985) in which learners' drawings were analysed for mental models of matter in the gaseous phase. This study deductively used these previously identified drawings as a coding scheme for classification of the learners' drawings. The coding scheme is provided as appendix XI. The type of inductive approach used in this study was the semantic approach. The semantic approach means that the themes are identified superficially without looking at anything beyond what is said or drawn (Kirschner, Sweller, & Clark, 2006). The semantic approach was used considering the age of the participants being in grade 4, that they may unlikely say something different from what they mean and that their drawings should represent what they understand. The themes in this study were the continuous model, continuous empty model, continuous animistic model, continuous particulate model, and the particulate model. The particulate model is the scientifically accepted model. The continuous model is a scientifically unaccepted conception since it assumes that matter is not made up of particles but of a continuous design. The continuous particulate model, in this study, is the transition of learner understanding from continuous understanding to particulate understanding.

All coding was done on *Atlas.ti* software which made the responses much easier to code. The reliability of the coding system was tested by the participation of my supervisor, who used the same semantic, inductive-deductive thematic approach to code half of the data. Afterwards a discussion of the codes and themes was done. In most of the codes there was similarity in how my supervisor and I coded the data. My supervisor, however, advised me to allow emerging codes to appear without trying to associate them with already existing codes while they are not. Thus, learners' responses in the form of drawings, interviews and field notes constitute qualitative data. Deductive and inductive coding Nieuwenhuis (2011) was used for coding and for categorizing drawings into continuous animistic, continuous, continuous empty, continuous particulate, and particulate as described in table 2.1 in section 2.2 above.

Table 3.10 below was used as a guide during the qualitative data analysis. Much detail about the way learners' responses were coded and classified was based on the coding scheme provided as appendix XI. It should be noted that the design of the coding scheme was based on the one previously used in a study by Novick and Nussbaum (1985).

Table 3. 10 Criteria used to classify learner responses as evidence of a possible misconception or correct understanding per test item

Question	Concept being tested	Possible misconception	Correct understanding
Q1	Nature of gas -particulate/ continuous	- Continuous model - Animistic behaviour. - Particles confined at the top or bottom or to the sides of flask.	-Particulate nature of gas particles. Evenly spaced. Evenly filling the space of the container from top to bottom.
Q2	Nature of gas -particulate/ continuous.	-Continuous model -animistic behaviour. -increase in number of particles. –particles confined at the top or bottom or to the sides of flask.	-Particulate nature of gas particles. Evenly spaced. Same number of particles. Increase in space between particles
Q3	Nature of gas -particulate/ continuous. -space between particles.	-Continuous model -animistic behaviour. -particles confined at the top or bottom or to the sides of flask.	-Particulate nature of gas particles. Evenly spaced. Some particles also in the syringe.
Q4	Nature of gas -particulate/ continuous.	-Continuous model -animistic behaviour. –particles confined at the top or bottom or to the sides of flask.	-Particulate nature of gas particles. Evenly spaced. Increased number of particles.
Q5	Nature of gas -particulate/ continuous.	-Continuous model -animistic behaviour. –particles confined at the top or bottom or to the sides of flask.	-Particulate nature of gas particles. Evenly spaced. Same number of particles.

3.6 Credibility and dependability of data collection instruments

In this section the credibility and the dependability of the various instruments used for data collection are discussed.

3.6.1 The pre-test

The pre-test (appendix I) was made by adapting part of the test instrument already used in a similar study reported in a book titled "Children's Ideas in Science" (Novick & Nussbaum, 1985). The study by Novick & Nussbaum (1985) focused on all the three states of matter, but the current study only focused on the gaseous phase. The pre-test was composed of five questions in which learners were required to draw air in different containers and different situations assuming that they wore magic glasses which would allow them to see the air. The pre-test was structured in a way that gave consideration to the grade 4 learners' thinking and learning levels.

3.6.1.1 Credibility of pre-test instrument

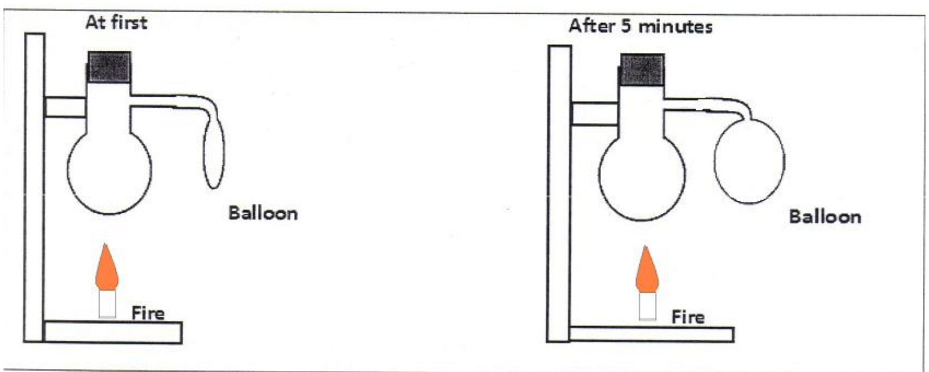
The pre-test was assumed credible on the basis of how it was constructed, in that it included items adapted from already tried and tested test instruments by Novick & Nussbaum (1985). After preparation of the pre-test the instrument was evaluated by two experienced lecturers for content and face validity. At the recommendation of the experienced lecturers, the pre-test was also evaluated by grade 4 educators of the classes which participated in the study, before the instrument was used. All the grade 4 educators were satisfied with the content, level of difficulty and face validity of the instrument and agreed that it would meet its intended objective.

During the administration of the pre-test, the researcher read and explained every question for the learners. This was done to avoid misunderstanding or incorrect interpretation of the questions by the learners. During the administration of the pre-test, the learners asked questions seeking clarity, and were answered fully by the researcher. This will be discussed in section 4.1.1 below.

3.6.1.2 Dependability of pre-test instrument

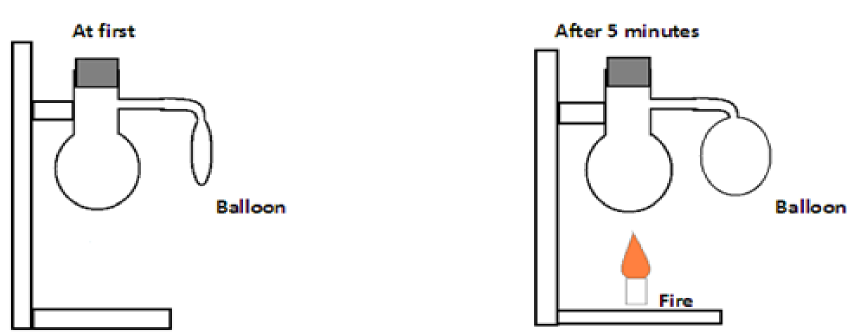
To further test dependability of the pre-test, the instrument was given to two grade five classes at one of the sample schools. The learners answered the test and their responses were analysed by the researcher. The analysis showed some sections in the pre-test needed to be modified and were changed accordingly. For example, in question two of the instrument, there was an empty flask and balloon on the lateral tube before and the same equipment after heating. Initially, there was a burner at the bottom of the flask before heating. The burner seemed to indicate that there was heating supplied to the first flask as well. The diagram was as shown in figure 3.7 below.

Figure 3. 7 Diagram showing questionnaire item 2 prior to modification



The presence of the burner in the first flask showed no difference between the flask before heating and the flask after heating. After the pilot study, the burner was removed from the first flask. The diagram which was used in the pre-test and the post-test in the final study was as shown in figure 3.8 below.

Figure 3. 8 Diagram showing how questionnaire item 2 was modified



3.6.2 The initial and final group interviews

The interview schedule (appendix II) for learners was also constructed by adapting the interview schedule used in studies reported in "Children's Ideas in Science" (Novick & Nussbaum, 1985). The aim was for learners to explain the meanings of their drawings.

3.6.2.1 Credibility of group interviews

The instrument was also credible based on the way it was constructed based on the study by Novick and Nussbaum which was used in their 1985 study. In this study the instrument was also evaluated for credibility by two university lecturers. The lecturers focused mainly on whether the questions were probing for answers to the research question. The instrument was also evaluated by four experienced grade 4 educators who focused on the accessibility of the questions to the grade 4 learners in terms of language used.

3.6.2.2 Dependability of group interviews

The group interviews were based on the work by Novick and Nussbaum (1985). The instrument therefore was dependable since it had been applied in that previous study and yielded results. The interviews were done during a pilot study in two grade five classes to check dependability of the instrument. After administration in the pilot study, there was not much change done to the interview schedule. The instrument was producing data for which it was intended; that is, the description of learners' diagrams.

3.6.3 The post-test

The post-test items, just like the pre-test ones, were adapted from test items used in instruments in similar studies as reported in "Children's Ideas in Science" Novick & Nussbaum (1985). The post-test was composed of five questions of similar contexts to the pre-test. Learners were required to draw air in different containers in different situations. The post-test was structured considering the grade 4 learners' thinking and learning levels.

3.6.3.1 Credibility of the post-test

Just like the pre-test, the post-test was constructed based on the study by Novick and Nussbaum (1985), and was further evaluated for credibility by two university lecturers. They focused mainly on whether the questions were probing for answers to the research question and if it was still congruent to the already credible instrument which formed the background of this study. The instrument was also assessed by four experienced grade 4 educators who focused on whether the language used would be accessible to the grade 4 learners.

3.6.3.2 Dependability of post-test

The dependability of the post-test was based on the fact that it was adapted from an already existing instrument by Novick and Nussbaum (1985). Two university lecturers also assessed the post-test for dependability.

3.6.4 The interview for educators

The interview for grade 4 educators was meant to collect information about their observations of the inquiry lessons. The interview aimed at obtaining the educators' impressions of the inquiry method they observed assuming that they did not know inquiry teaching. The educators were supposed to focus on learners' activities and the approach of the inquiry method, as compared to the lecture method. The comparison done by the educators was based on the assumption that they normally used lecture method and not the IBSE method,

The specialist lecturers evaluated the interview schedule (appendix III) for credibility of the interview schedule for educators. The lecturers were satisfied that the interview questions would assist me in getting information needed to answer the research questions. This was done to ascertain the dependability of the instrument.

3.6.5 The follow up test

A follow up test (appendix VIII) was constructed and given to the same learners in both classes at both schools four months after the learners were taught and had written the post-intervention test. This test was given to assess whether learners' responses obtained would be consistent with their responses observed in the post-test. This test was testing retention of post-intervention results. The follow up test was a multiple choice test including distractors of a variety of possible drawings which the learners drew themselves in the post-test and classified by the researcher into mental models. The follow up test was constructed by the researcher and was verified by the supervisors. The learners were not informed about the test before they wrote it. Therefore, the learners had not prepared for the test but wrote it as a surprise test.

An example of one question from the follow up test is as shown below:

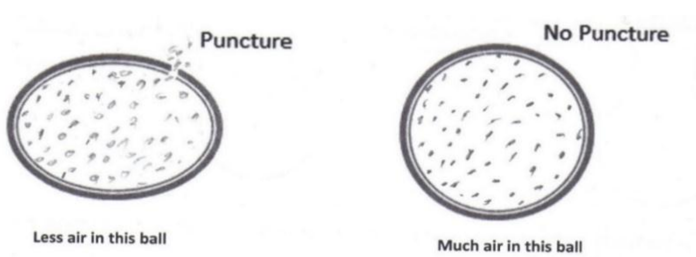
Question 2

Learners were given two identical soccer balls **one with a puncture a**nd another **without a puncture**.

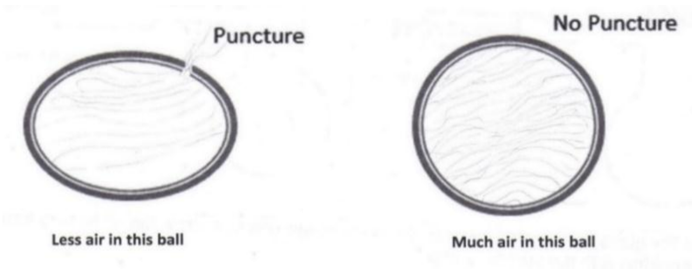
Less air in **Much air in**

Which of the following responses shows the correct drawings of air in the two balls above? **Choose the best answer.**

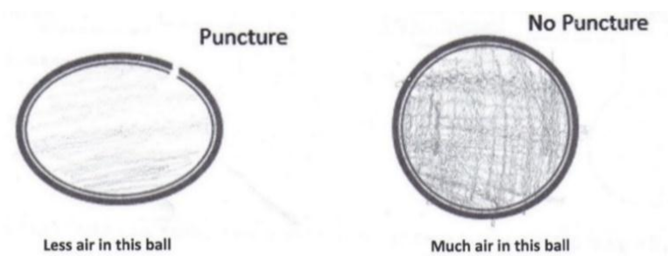
A



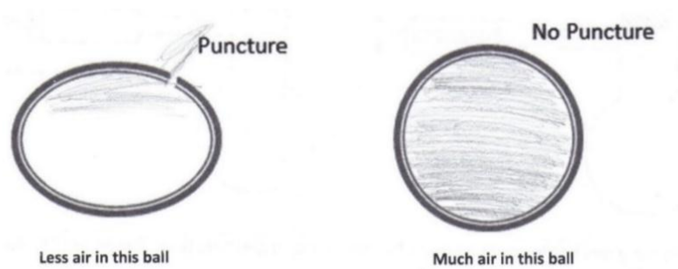
B


Puncture
No Puncture
Less air in this ball
Much air in this ball

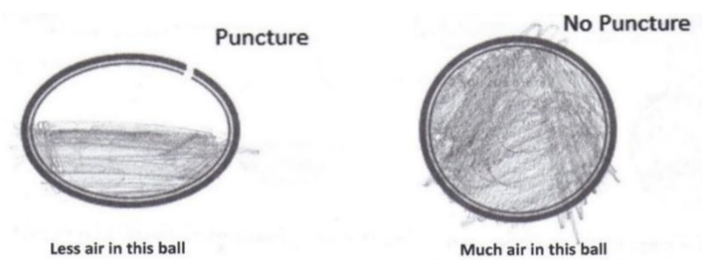
C


Puncture
No Puncture
Less air in this ball
Much air in this ball

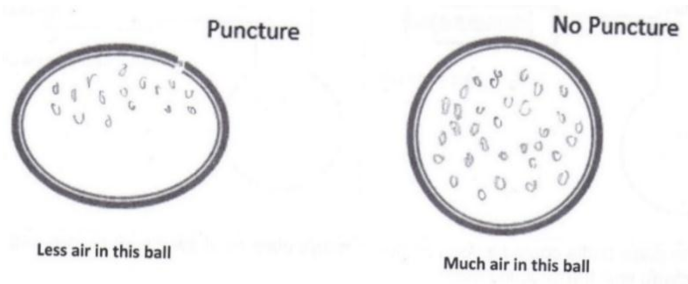
D


Puncture
No Puncture
Less air in this ball
Much air in this ball

E


Puncture
No Puncture
Less air in this ball
Much air in this ball

F



The results from the follow up test were tabulated and analysed. Comparison was made between the post-intervention results and the follow up test. The results indicated that there was retention of concepts in both the inquiry group and the lecture group. The inquiry group had a higher retention of the particulate conception than the lecture group.

3.6.5.1 Credibility of the follow up test

The test was a multiple choice test constructed using learners' responses in the post-test. The responses were classified according to the themes which were the main mental models observed during data analysis. These were the continuous model, continuous animistic model, continuous empty model, continuous particulate model and the particulate model. The instrument was checked for content and face validity by four experienced grade 4 educators and my supervisors.

3.6.5.2 Dependability of follow up test

The test was checked by two university lecturers that it would continue to produce the same results. The test consisted of multiple choice questions which were read and explained to the learners to make sure that they understood the questions. The learners were only required to select the correct answer from the choices available.

3.7 Ethical considerations

The research was complied with all ethical considerations as required by the ethics committee of the University of Pretoria. The proof for satisfying all ethical considerations for this study is indicated in the ethical certificate on page ii and the letter of permission to go for field-work which is appendix XII. An application letter for ethical clearance was submitted before any data collection took place. After getting ethical clearance with the Gauteng Department of Education then application for ethical clearance by the University of Pretoria was lodged. After getting ethical letter of permission to do field work (appendix XII), fieldwork started. When the principals agreed and signed the letters of consent (appendix VI), the grade 4 educators who agreed to participate in the study were also given letters of consent (appendix XIII). The grade 4 learners were given letters of consent (appendix IV) for their parents or guardians asking permission for their children to participate in the research. Learners who had permission from parents or guardians and were also willing took part in this study, were given letters of informed ascent (appendix V). After all this had been done data collection commenced.

No person was forced to take part in the research unwillingly. Learners involved participated willingly in the research and were informed that they were free to withdraw their participation if they wished to do so without any repercussions.

All data obtained from this research was used for educational purposes only and with strict confidentiality. Pseudonyms were used in all recordings and no names were required on the tests. The actual names of the school or participants were not used. The data is kept in safe storage with the University of Pretoria in accordance with the University regulations. The researcher did not keep any data in the form of recording of interviews or transcriptions thereof, questionnaires or field notes for any reason. All raw data was surrendered to the University after all the data required for analysis had served its intended purpose in the study.

3.8 Summary

A variety of instruments were used to collect data before, during and after the intervention. All data collected were loaded into a software programme for qualitative data analysis, *Atlas.ti* version 7 for careful coding and categorizing into previously identified models and into other categories observed in this current study. The initial understanding of learners was established by analysis of the pre-test and the first group interviews.

During the intervention the researcher and the grade 4 educators observed the inquiry lessons. The researcher made field notes of the activities of the learners during the lessons. Educators of the inquiry group were interviewed after the intervention. The new understanding of learners was established by analysing the qualitative data from the post-test and the second group interview.

Four months after the post-test a follow up test was applied to the learners. The multiple choice test was constructed using the same learners' responses in the post-test. The purpose was to crystallize the findings so as to show the trustworthiness of the results. The next chapter will focus on the data analysis of this study.

CHAPTER 4 RESULTS AND DISCUSSION

4.0 Introduction

This chapter focusses on the presentation and discussion of the data collected using the various instruments of data collection discussed in chapter three. Presentation and discussion of results will follow in sequence: first the presentation of results obtained through the pre-test for the inquiry and lecture groups, secondly, the intervention and events as they occurred and observed during implementation of the intervention will be discussed, and, lastly, the post-intervention results will be presented and discussed first for the inquiry group and then the lecture group. An overview of how the results of all pre-tests compare to the results of all the post-tests for both the inquiry and the lecture group will follow.

4.1 Data analysis

This section is a discussion of the pre-test results and the first group interview data for each of the four classes. Since the purpose of the group interviews was to seek clarification on the learners' responses in the pre-test, in this section a combination of the pre-test results and the group interview data are referred to as pre-intervention results. In the same way a combination of the post-test and the second group interview data is presented as post-intervention results. First is the discussion of the pre-intervention results and then the post-intervention results. Subsequently there is an elaboration of the field notes to enrich both the pre-intervention results and the post-intervention results. The field notes were used as a data source helping in the triangulation of the findings. Then, lastly, there is a comparison between the pre-intervention and the post-intervention results to reveal the effect of the teaching approach on learners' understanding of matter in the gaseous phase.

In the following paragraphs, the findings as obtained from categories using *Atlas.ti* version 7 are presented and discussed. In each section the focus is to answer the research questions above and ultimately answer the primary research question of the study.

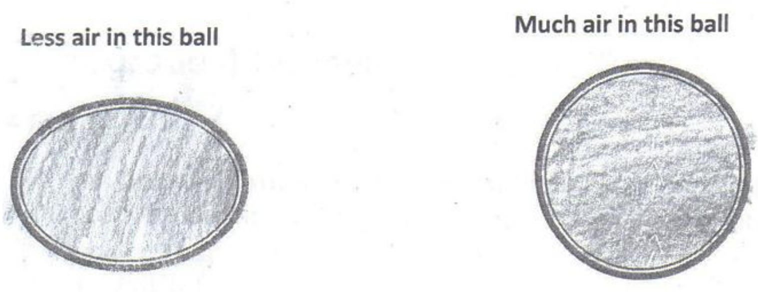
4.1.1 Pre-intervention results

To establish the initial understanding of learners, a pre-test was administered to the four classes and the initial group interviews were conducted. The data revealed the initial understanding of the learners on matter in the gaseous phase before intervention. This answered the first research question of the study. During the pre-test, learners asked many questions, seeking clarification from the researcher. Some of the questions asked by the learners were *"Air cannot be seen; so how do you expect us to draw it?"* some were saying *"Do you think it is possible?"* Some were saying "*It doesn't make sense"*. Some learners could be seen looking puzzled and on some occasions they would look at each other and shake their heads, and some would laugh. This seemed to indicate that the learners had no idea about how they could draw air even that it could be represented in some way on paper. It seemed to mean that these puzzled, seemingly confused learners did not have mental models of invisible air. The researcher explained that the learners were supposed to imagine that they had magic glasses on, which would allow them to see air. After some time, the learners gradually started to answer the questions. In the paragraphs that follow are the various responses of the learners in the pre-test and group interview responses. I will then present how these responses were interpreted using examples of drawings as illustrations.

4.1.1.1 Continuous conception of learners in the pre-test

In the pre-test many learners in both the inquiry and the lecture group represented air by smooth shadings, curved line shadings or both smooth and curved line shadings. An example of the drawings learners made using smooth shading is as shown in figure 4.1 below.

Figure 4.1 Example of learners' drawings showing smooth shading to represent air



It emerged during the group interviews that learners use the smooth shading and curved line shading interchangeably referring to the same continuous conception. Figure 4.2 below shows the learners' curved shading drawings some learners made to represent air.

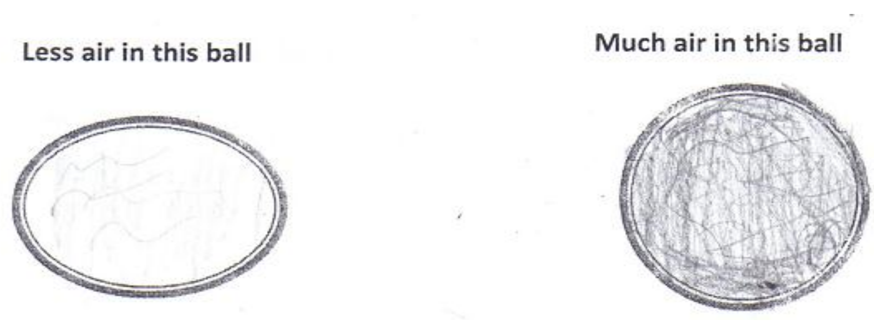
Figure 4. 2 Curved line shading representing air

Some learners made smooth shadings as shown in figure 4.1 while others drew curved-line shadings as shown in figure 4.2 above. Some learners made drawings which showed a mixture of curved line shadings and smooth shading to represent air. Figure 4.3 below shows a drawing of a combination of curved line shading and smooth shading. In the initial group interview it emerged that these two kinds of shadings were interchangeably used. Sometimes these drawings were used together in the same drawing representing the same thing. In some instances, the smooth shading was used to represent more air while the curved-line shading represented less air. The learners said there is no space in between thereby implying continuous conceptions.

Figure 4. 3 Combination of curved line shading and smooth shading.

The combined drawing of curved lines and smooth shading seemed to show that learners were undecided on how to draw air before formal instruction on the topic. In the initial group interview it emerged that these two kinds of shadings shown in figure 4.1, 4.2 and 4.3 were interchangeably used. The learners confirmed that the curved line shading, the smooth shading and the combination of them, means the same thing. The learners said there is no space in between thereby implying continuous conception. In some answers the curved line shading or the smooth shading was made in such a way that the container with more air would be darker than the container with less air as shown in figure 4.4 below. During the group interview when asked why the second ball is darkly shaded, the learners' responded that *"there is more air*".

Figure 4. 4 Shading is darker when there is more air



Continuous ideas from the Novick and Nussbaum study

The study by Novick and Nussbaum (1985) had similar results with the continuous conception being represented as in figure 4.5a or 4.5b below. The first drawing was used to represent more air in the flask and the second one to represent less air. The learners in the study by Novick & Nussbaum (1985) used smooth shading in this case, to represent continuous model.

Figure 4. 5 Continuous model drawing from Novick and Nussbaum (1985)

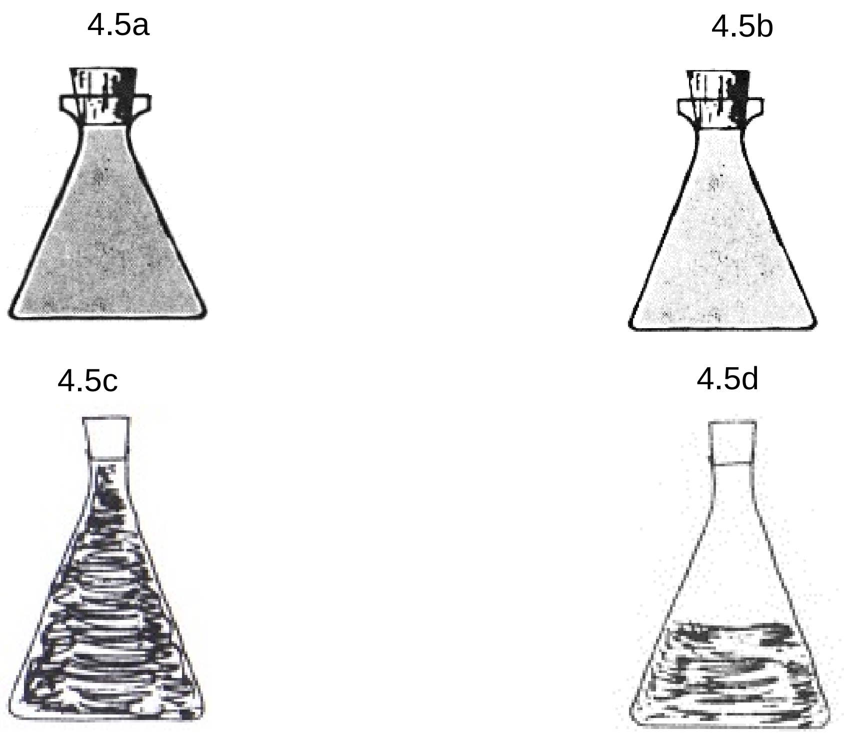
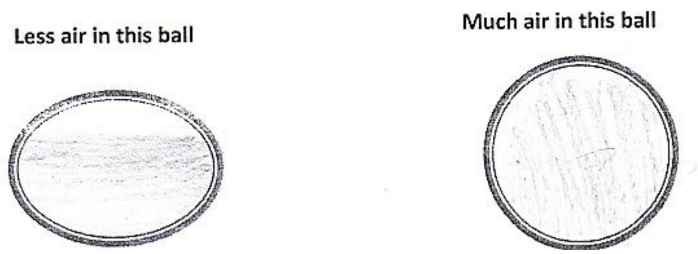


Figure 4.5c seems to show curved line shading also done by the learners in the previous study to represent continuous model. Figure 4.5d seems to show curved lines shading. This is consistent with the continuous animistic model in which the air is like settled at the bottom leaving the upper part empty.

4.1.1.2 Continuous animistic model in the pre-test

Some drawings in the pre-test showed learners believed that a ball with less air has an empty space in the upper part and air is settled at the bottom. In the ball with much air the shading seems to indicate that air is filling the whole container. There is also darker shading in the ball with much air. Therefore, the shading stands for air and the volume of shading stands for the amount of air. Smooth shading showing the continuous animistic model is shown in figure 4.6 below.

Figure 4. 6 Continuous animistic drawing air settling down (smooth shading)



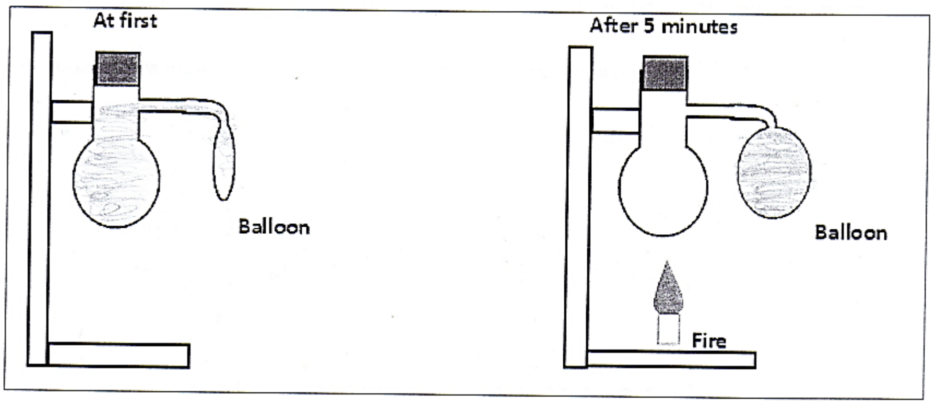
Some learners interviewed said in the ball with less air '*there is no air at the top*' meaning that air is settling down. As shown in figure 4.6 above there is some empty space at the upper part of the ball. The bottom part is shaded implying the continuous model. Some learners made curved line drawings instead of the smooth shading. Such drawings are like figure 4.7 below.

Figure 4. 7 Continuous empty drawing air settling down (curved shading)

During the group interviews, it emerged that both the curved line shading and the smooth shading mean the same thing. Both shading implies the continuous empty model.

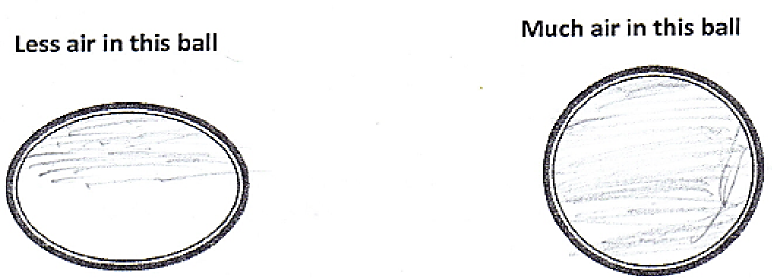
In some cases, learners would shade the upper part of the container and reason that *'there is fire at the bottom'*. Such drawings are like figure 4.8 below. In the first flask there seems to be complete shading of the flask and balloon, before heating. In the second drawing shading is only confined to the balloon indicating that air has literally *'run away'* from the fire below the flask. This implied that learners believed that air particles behave like animals thereby implying continuous animistic model.

Figure 4. 8 Continuous animistic drawing of air 'running away from fire'



In other cases, some learners showed animistic drawings in the sense that they made shading at the top only, leaving the bottom part of container unshaded like figure 4.9 below. The drawing implies that air is confined only in the upper part of ball with less air.

Figure 4. 9 Continuous animistic drawing of air confined to the top

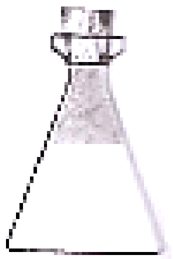


Continuous animistic ideas from Novick & Nussbaum (1981)

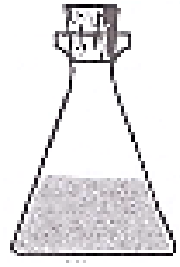
In the previous study by Novick & Nussbaum (1981) learners also had the continuous animistic model. Those learners represented air as is shown in figure 4.10 below. Figure 4.10a shows shading in the upper part of the container. The learners believe that air should always go upwards. In figure 4.10b learners assume that air is sitting down or resting and that's why they shade the bottom only. In both cases learners with this conception do not believe that air will fill the whole container but be confined to some part of the container.

Figure 4. 10 Continuous animistic drawings from Novick & Nussbaum (1981)

4.10a



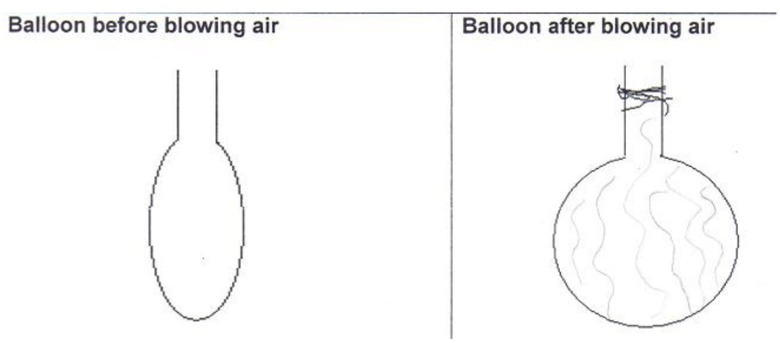
4.10b



4.1.1.3 Continuous empty model drawings

Drawings like the figure 4.11 below show that some learners believe that a balloon before blowing in air is empty without anything in it. The second drawing shows that the learners have a continuous conception as shown by the shading.

Figure 4. 11 Continuous empty drawing with first balloon empty

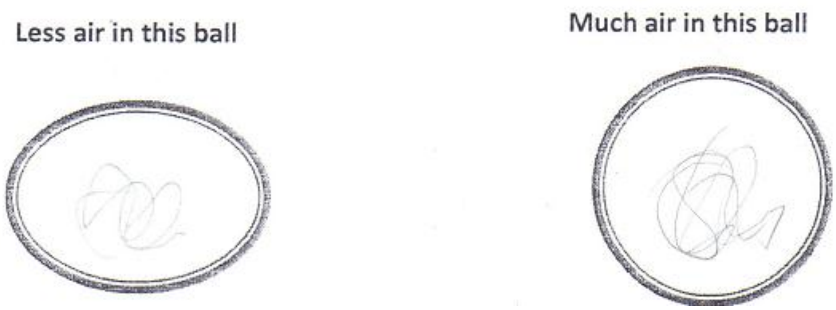


In other cases, learners made drawings like figure 4.12 below. Air seems to be confined at the centre of the ball and the outer parts seem to be empty. This implies a continuous empty model since the centre is shaded and the outer parts are not shaded.

Figure 4. 12 Continuous empty drawing with shading at the centre

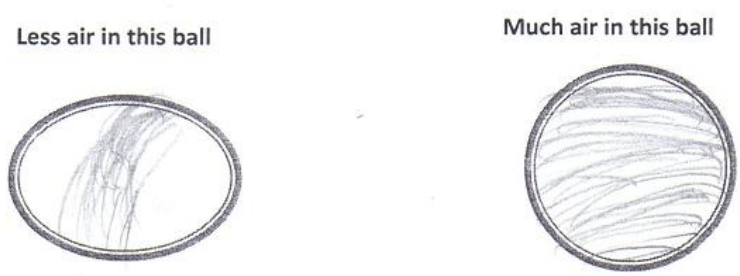
In other cases, learners made curved line drawings to represent air following the continuous empty model. Shading is as well confined to the centre of the ball and empty space at the edges. Such drawings are like figure 4.13 below.

Figure 4. 13 Continuous empty drawing with curved line shading



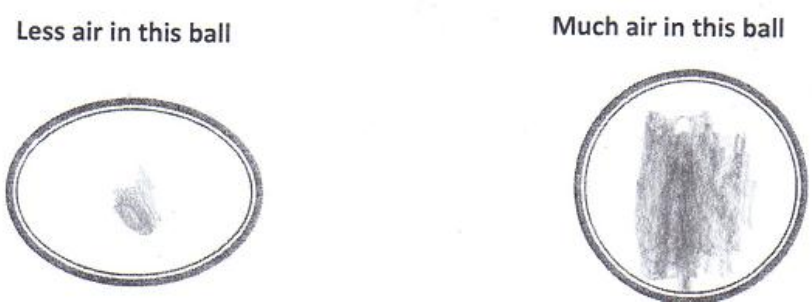
In a similar case shading is confined to the centre of the ball with less air. The second ball has more curved lines than the first. This implies that more air is represented by more curved line shading. In other cases, learners made drawings at the centre with the left and right sides empty. Such drawings are like figure 4.14 below.

Figure 4. 14 Continuous empty drawing with curved shading at the centre



In yet other cases, smooth shading was used by some learners instead of curved line shading. The outer parts of both balls are empty while the centre is shaded. There is more shading in the ball with much air than in the ball with less air. Such drawings are depicted in figure 4.15 below.

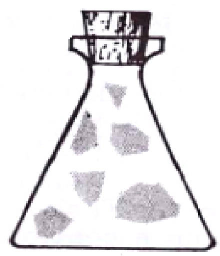
Figure 4. 15 Continuous empty drawing with smooth shading at the centre



Continuous empty ideas from previous study

The learners in the study by Novick & Nussbaum (1981) also depict the continuous empty model as shown in figure 4.16 below. There was, however, some difference with what learners in the current study did. While in the previous study learners drew many patches separated by blank spaces, learners in the current study just made a complete shading leaving a large blank space.

Figure 4. 16 Continuous empty model from Novick & Nussbaum (1981)



4.1.1.4 Continuous particulate drawings

The continuous particulate model is when learners make continuous drawings with space between the shadings, or when learners make shadings together with dots. Some drawings like figure 4.17 below show that learners used dots to represent air in the first drawing and curved lines in the second drawing. This seems to show that such learners had a continuous view as well as a particulate view. The model is therefore a representation of the continuous particulate model.

Figure 4. 17 Continuous particulate drawings made by the same learner indicating mixed view

Some learners made drawings like figure 4.18 below. In this drawing dots are mixed with curved lines shading. Since the curved lines shading stand for continuous conception and dots stand for particulate conception, then the drawings below stand for the continuous particulate model.

Figure 4. 18 Continuous particulate drawings in same drawing

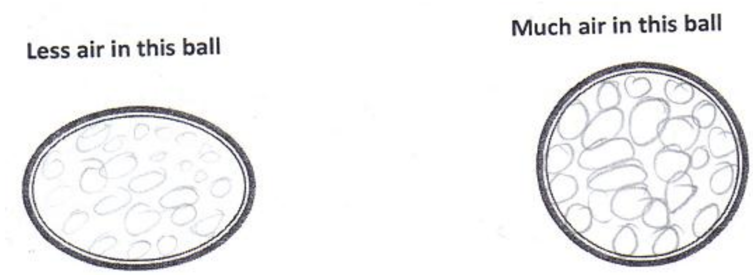
4.1.1.5 Particulate conception of learners in the pre-test

In the pre-test very few learners in both the inquiry and the lecture group made particulate drawings. These few learners who had particulate conceptions made drawings using dots like the one shown in figure 4.19 below. It seemed that these few learners were aware of the particulate model and the existence of a vacuum between particles.

Figure 4. 19 Particulate model shown by dots to represent air

Other learners also drew air using circles rather than using dots. The group interview confirmed that the circles represent air. This was also consistent with the study by Novick & Nussbaum (1981). An example of such a drawing is shown in figure 4.20 below.

Figure 4. 20 Particulate model shown by circles to represent air



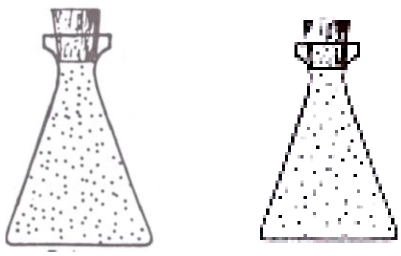
In the first group interview it emerged that learners drew circles and dots to represent gas particles. They, however, did not use the word *'particle'* but when the researcher asked them what the circles or dots stand for, they said *'the dots are the air'* or *'the circles stand for the air'*. Also when asked about the space between the circles or dots like in figure 4.19 and 4.20 above the response was that *'between them there is no air'*. Therefore, these few learners seemed to have a conception of vacuum even before instruction.

Particulate ideas from previous study

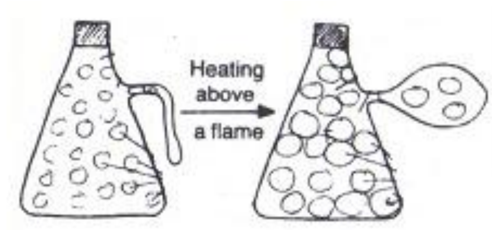
The diagrams in figure 4.21 below show the particulate views of learners who participated in the previous study (Novick & Nussbaum,1985). It is clear that they used dots just like children in the current study to represent air as shown in figure 4.21a. They also used circles to represent air just like children in the current study as shown in figure 4.21b.

Figure 4. 21 Particulate model in the study by Novick & Nussbaum (1985)

4.21a



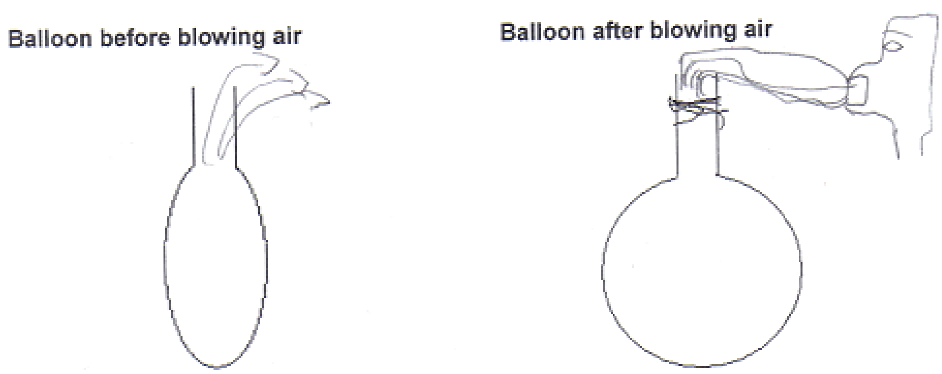
4.21b



4.1.1.6 Drawings which are not clearly understandable

The researcher should also state that some drawings the learners made in the pre-test were not easy to understand or maybe they could be meaningless. Example of such a drawing is shown in figure 4.22 below.

Figure 4. 22 Drawings which are not clearly understandable

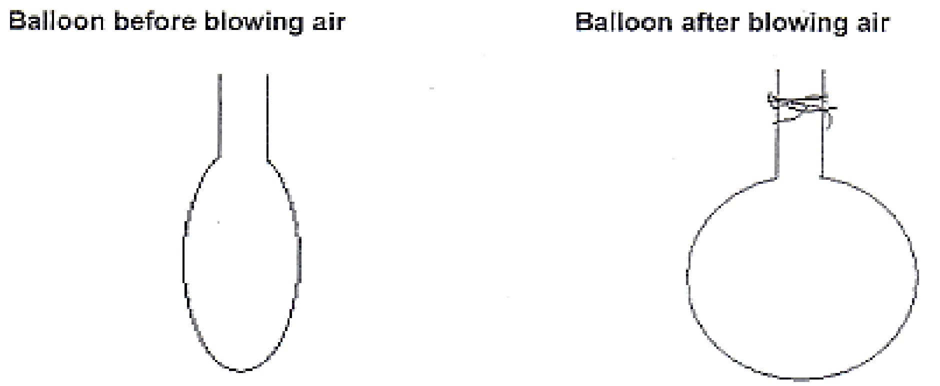


This learner probably did not have a conception of matter in the gaseous phase since air is considered invisible and therefore such learners do not have a mental model to represent matter in the gaseous phase. This was also supported by some responses learners gave in the initial group interview, and the many exclamations which they made in class in questions like *“is it possible to draw air which we cannot see?”* More detail has been discussed in 4.22 above.

4.1.1.7 Empty model in the pre-test

Learners sometimes left the shapes without putting in any drawings. Such responses are as in figure 4.23 below:

Figure 4. 23 Empty drawings

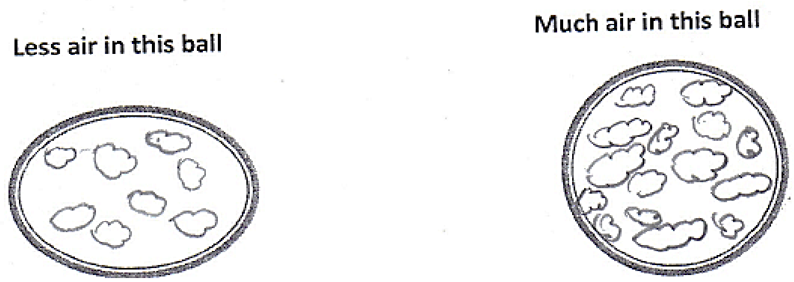


In the case of the empty model it was not clear whether the learners did not have time to draw or they already assumed it is okay since initially they had said, *'How can we draw air which cannot be seen?'*

4.1.1.8 Emerging ideas in the pre-intervention results

Some emerging ideas were identified in the pre-test and the first group interview. These were interpreted as emerging ideas as they deviated from what had been reported in the literature but they seemed to be meaningful. Such drawings were like figure 4.24 below. The items drawn here initially appeared to me like the circles representing the particulate view as in figure 4.20 in section 4.1.1.5 above. Careful analysis revealed that the shapes drawn in this case are not circles but rather are like clouds.

Figure 4. 24 Emerging ideas in drawing (cloud shaped)

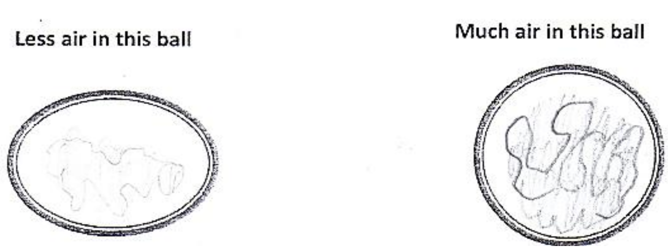


These drawings just like figure 4.25 below seem to show some kind of continuous empty model in that in the cloud-shapes it appears to mean that air is clustered and there is a vacuum between the clusters. It seems as if such drawings have not been identified in previous studies on the same topic.

Figure 4. 25 Emerging ideas in drawings (cloud shaped second variation)

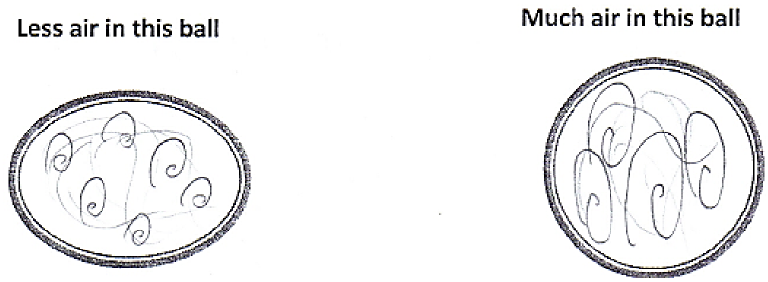
Another variation of the *'cloud shaped drawing'* is shown in figure 4.26 below. The drawing seems to show a continuous view of air in that the drawing looks like one object. This kind of drawing has not yet appeared in a previous study. For that reason, in this study it was decided to classify it under *"emerging ideas"*.

Figure 4. 26 Emerging ideas in drawings (cloud shaped third variation)



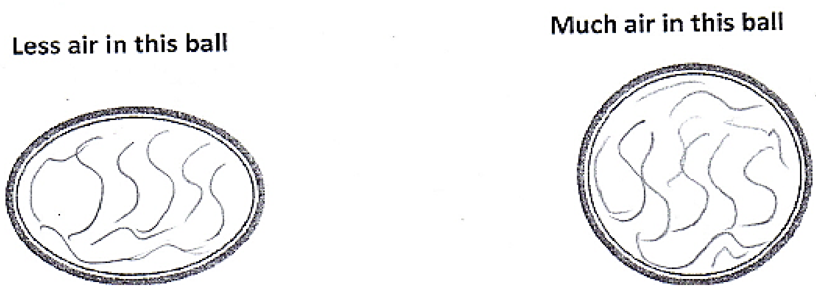
Another new idea is shown in figure 4.27 below. The objects may to seem appear like an ordinary shading but it seems as if the objects are following a specific shape. The objects seem to be standing for something like in the particulate view. In figure 4.27 below it appears the objects get bigger in the ball with much air. It seems to mean that such a view is of the idea that the coils just unfold and increase in volume.

Figure 4. 27 Emerging ideas in drawing (coil shaped objects)



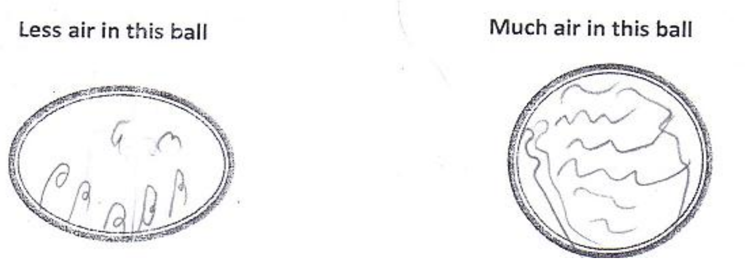
Some of these emerging ideas also are like figure 4.28 below. The drawings seem to show some kind of particulate view but the shape of the object is quite different from the current particulate view. These objects are S-shaped as opposed to a dot or a circle. If this idea were to be particulate, then the shape of the particle would still be different from the currently accepted model. I could not classify these drawings under the continuous view because the S-shaped objects seem not to represent some form of shading. They appear like having a specific shape.

Figure 4. 28 Emerging ideas in drawings (S-shaped objects)



In some cases, there appeared combinations of the coil shaped and the S-shaped drawings like in figure 4.29 below. It appears that the coil shaped and the S-shaped views may be used interchangeably and that they may be meaning the same thing. It is not clear what these shapes actually stand for.

Figure 4. 29 Emerging ideas in drawings (combination of coil and S-shaped objects)



In the first group interviews some emerging ideas also emerged like *"air is like roots"*. And in other cases learners said *"unshaded space in the container stand for air"*. It appears as if learners in this case abhor the existence of a vacuum. The learners with this view, however, use shading in drawings showing that they have some continuous view. However, when learners said *"unshaded area represent air"* then, it is not clear what the shaded area stands for.

These drawings cited above are not exhaustive of all the emerging ideas which were identified. These are just part of a wide variation of such drawings. In this study emerging ideas in the pre-test and the first group interview represented 9% in the inquiry group and 18% in the lecture group.

4.1.1.9 The initial understanding of learners in the inquiry group

The results on the pre-test and initial group interview constitute the initial understanding of learners. As shown in table 4.1 and figure 4.30 below in section 4.1.1.10, at school A 6% of the learners in the inquiry class held the particulate model while 49% of the learners held the continuous conception. In the same class 12% of learners held the continuous animistic model and 20 % held the continuous empty model while 2% held the continuous particulate. There were 7% empty models and 5% emerging ideas in the pre-test inquiry group at school A.

For the inquiry group at school B 40% of the learners held the continuous conception while 1% held the particulate conception. The continuous particulate conception was at 0% while continuous animistic and continuous empty were at 2% and 33% respectively, and empty model was 11% and 12% of the learners' conceptions were emerging ideas.

On average for both inquiry classes the percentage of particulate conception at school A and B was just 3% and continuous particulate conception was just 1%. The percentage of continuous conception was 43% while the continuous animistic was 6%. The continuous empty model was 28%, the empty model was 10% and the percentage of emerging ideas was 9% on average in both inquiry classes in the pre-test.

4.1.1.10 Initial understanding of learners in the lecture group

As shown in the table 4.1 and figure 4.30 below, in the lecture group in school A 9% of the learners had continuous animistic model while 40% had continuous model. In the same group 13% of the learners held the continuous empty model and also 13% held the empty model. 6% of learners held emerging ideas while 18% held the particulate conception and there were none with continuous particulate conception.

At school B 11% of learners in the lecture class had continuous animistic model, 38% continuous conception, 19% continuous empty model, and 5% empty model. 25% of the learners held the emerging ideas, none held the continuous particulate model and only 2% held the particulate conception.

On average in the lecture group pre-intervention results had 10% of the learners with continuous animistic model, 39% with continuous model and 17% with continuous empty model. 8% had the empty model, 8% had particulate model, none with continuous particulate model and 18% had the emerging ideas which could not be classified according to the already existing work by Novick & Nussbaum (1985).

The results indicate that there was not much difference between the inquiry learners' understanding compared to the learners in the lecture group. The difference shows a slightly higher particulate conception of 3% in the inquiry group as compared to 8% in the lecture group. This indicates that the two groups had comparable understanding to start with. More detail is shown in table 4.1 and figure 4.30 below. These results were obtained after coding and categorizing the results.

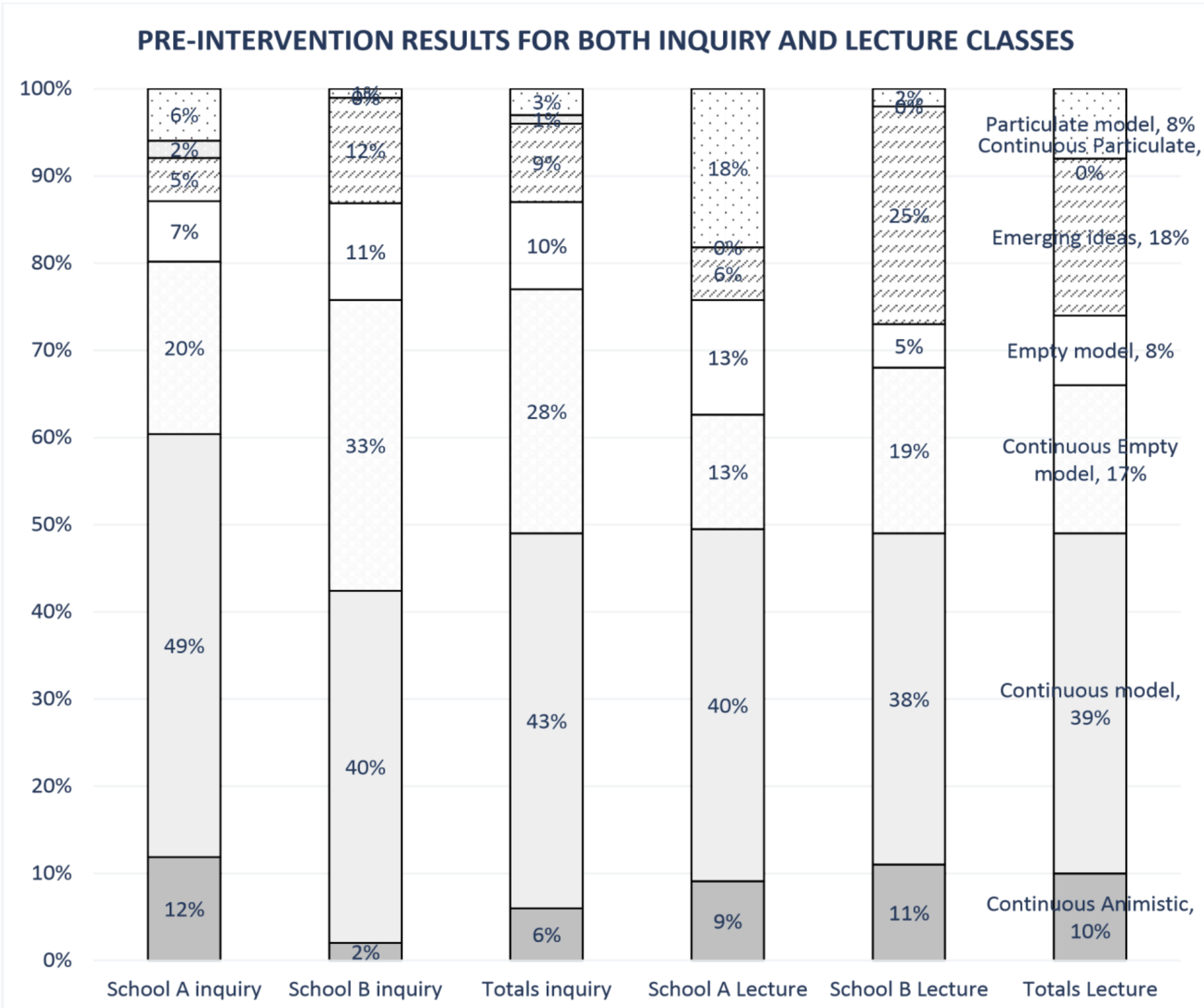
In the pre-test and the initial group interview, most of the learners in both schools had a continuous conception of matter as compared to the particulate conception. In the inquiry group there was 77% continuous conception while in the lecture group 76% of the learners had continuous conception of matter in the gaseous phase. Only 4% of the learners showed particulate conception in the inquiry group while in the lecture group there was 8% particulate conceptions of matter in the gaseous phase.

The initial conception of most learners on matter in the gaseous phase was summarily continuous model. In some cases, responses of learners also indicated that they did not have a mental conception of matter in the gaseous phase. In other cases, learners showed a mixture of continuous and particulate conception, which is being regarded as continuous particulate conception in this study. In the initial test and group interviews, some particulate conception existed although in a very small percentage.

Table 4. 1 Pre-intervention for both inquiry and lecture groups

	Inquiry group						**Lecture group**					
	School A		**School B**		**Totals**		**School A**		**School B**		**Totals**	
Learner's conception	**Frequency**	**Percentage %**	**Frequency**	**Percentage %**	**Frequency**	**Percentage %**	**Frequency**	**Percentage %**	**Frequency**	**Percentage %**	**Frequency**	**Percentage %**
Continuous Animistic	28	12	9	2	37	6	22	9	39	11	61	10
Continuous model	114	49	144	40	258	43	98	40	139	38	237	39
Continuous Empty model	46	20	118	33	164	28	33	13	69	19	102	17
Empty model	16	7	41	11	57	10	32	13	20	5	52	8
Emerging ideas	12	5	44	12	56	9	15	6	93	25	108	18
Continuous Particulate	4	2	1	0	5	1	1	0	1	0	2	0
Particulate model	15	6	4	1	19	3	44	18	8	2	52	8

Figure 4. 30 Graphical representation of the pre-intervention results for both inquiry and lecture groups



4.1.2 The intervention for both the inquiry and the lecture group

As explained in section 3.4.4.1 the lecture group was taught using the lecture method and the inquiry group was taught using the IBSE. The results on the initial understanding of learners in the pre-test and first group interviews indicated a lack of understanding of matter in the gaseous phase. The learners were puzzled and felt that what they were expected to write was difficult and unachievable. After the pre-test some learners asked the researcher for the results and others were asking for the correct answers to the questions. It was clear that the pre-test was a *'challenging test'* for the learners. The researcher's response was that the learners would be taught by experienced educators and they were going to understand matter in the gaseous phase. For this reason, the learners were very excited to have the experienced educators come in their midst. The learners were not aware of any difference in the teaching approaches used. The researcher just introduced the experienced educators to the learners as individuals who were going to help them understand matter in the gaseous phase.

In the next section is a brief description of the treatment given to the inquiry group followed by a brief description of the lecture method employed in the control group.

4.1.2.1 The inquiry group's results obtained during the intervention

The inquiry lessons were structured following the instruction framework in Bybee's 5Es model (Bybee, 2010). The model is prescriptive in terms of activities that both educators and learners need to demonstrate. The lessons were planned following the 5Es model and all the educator and learners' activities were structured likewise. The type of inquiry used was teacher-initiated inquiry (Blumberg, 2008; Llewellyn, 2011). Teacher-initiated inquiry is a type of inquiry method where the educator provides a problem, encourages learners to solve the problem, acts as a facilitator, guides and assesses learners (Lawson, 2010). Appendix IX shows the lesson plans used in teaching the inquiry group following the 5Es model.

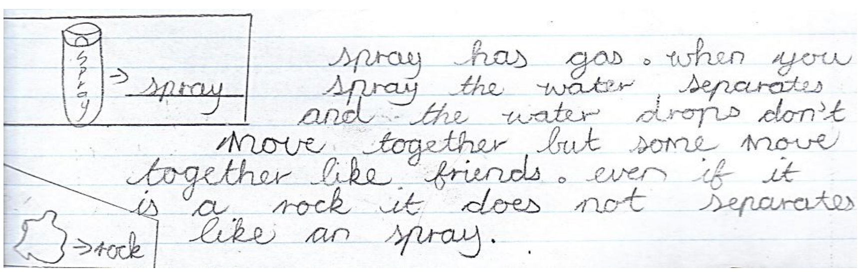
During the inquiry lessons, learners worked in groups in an organized manner. The learners constructed different models of their conception of matter in the gaseous phase. They discussed together and at some instances could be seen changing their initial ideas after discussion with other group mates. They asked the educator many questions and then sometimes they also asked the researcher during their group work. The learners at the end reported their models to the class, which in most cases were right. The experienced educators made corrections on a few of the reports from learners.

The interviews with the grade 4 educators of the inquiry group revealed a lot of other actions of learners observed in the inquiry lessons. Both grade 4 educators believed the inquiry method was going to work, given the age of the learners. They both commented how learners worked in small groups to come up with their own observations and presenting their findings to the experienced educators. The grade 4 educators revealed that the learners were more actively involved in constructive discussions on the work before them.

Class activity: Air particles can move

The first activity in the inquiry group was that of introducing learners to the particulate view and that gaseous substances can move. This was done using a spray. Figure 4.31 below shows a drawing by learners in one of the groups. Learners in this group identified that spray is made of gas. But the learners started to refer to the spray as water. A possible reason for this misconception may be that learners observed a liquid when spraying. The liquid is not water but learners at this stage called the liquid water. The animistic view is also evident when they said that particles *"move together like friends"*.

Figure 4. 31 Example of learners' drawings in the class activity about air movement



Further activities were done in the first lesson as part of the introduction. Figure 4.32 below shows the classification done by one group of learners in the inquiry group. They were asked to write only about five examples of each but ended up writing more than five. The researcher noticed that learners in this group gave a *"gas stove"* as an example of a gas. They also mentioned a 'fire extinguisher' as an example of a gas. This misconception may be referring to the powder that comes out during the operation of a fire extinguisher. Learners may have confused the powder pumped out at high speed to be a gas while the substance is a solid powder. These two were the only wrong ideas the learners in this group had.

Figure 4. 32 Examples of learners' list of items which are solids, liquids and gases

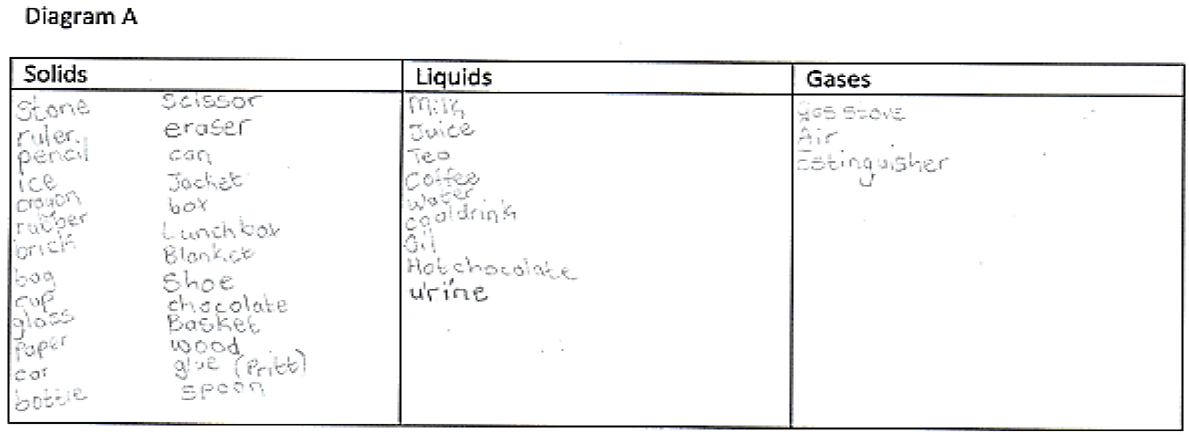
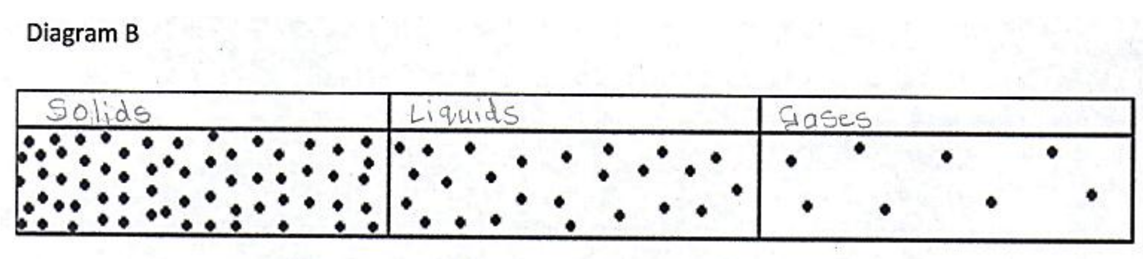


Diagram A

Solids		Liquids	Gases
Stone	Scissor	Milk	gas stove
ruler.	eraser	Juice	Air
pencil	can	Tea	Estinguisher
ice	Jacket	Coffee	
crayon	box	Water	
rubber	Lunch box	cooldrink	
brick	Blanket	Oil	
bag	Shoe	Hot chocolate	
cup	chocolate	urine	
glass	Basket		
paper	wood		
car	glue (Pritt)		
bottle	spoon		

The first activity was followed up by completion of the table in figure 4.33 below showing particulate arrangement in solid, liquid and gas. Most learners, like this group, got the correct classification according to particulate arrangement.

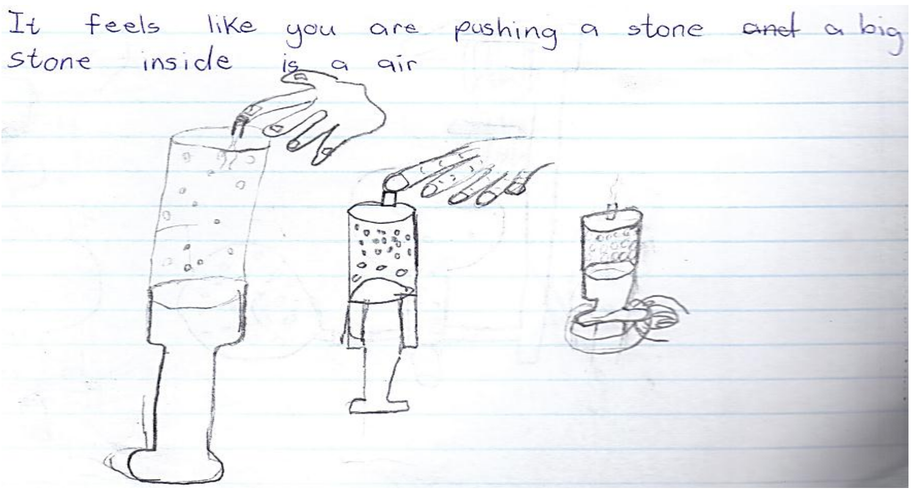
Figure 4. 33 Classification of solid, liquid and gas by particulate arrangement



Class activity: Compressing air in a syringe

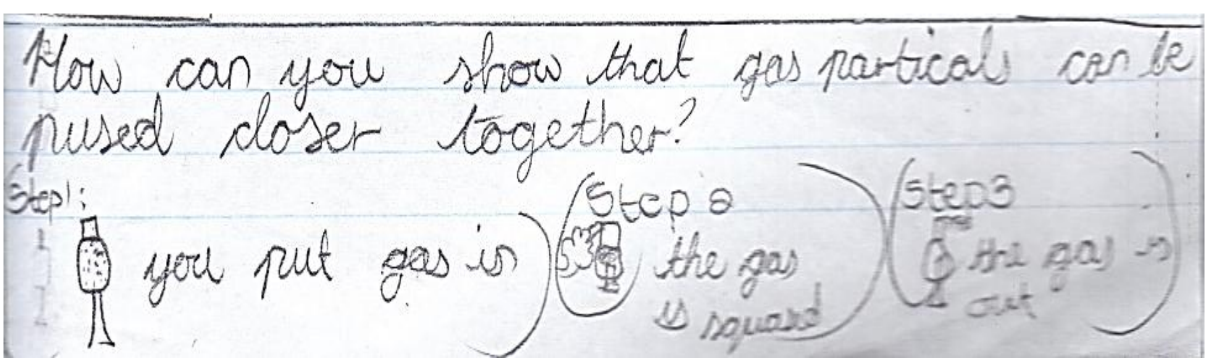
During task 1 of the second inquiry lesson, compression and expansion of gas in a syringe was done by learners in groups. Figure 4.34 below shows the work by a group of learners. In this case, the learners wrote down their observations and made these drawings. They said when they push the pump of the syringe it feels so hard like a stone. On the drawing the learners also drew the air before and after compression using the particulate view. It is clear that the space between particles before compression is much wider than the space between particles after compression. This shows that the learners had a correct idea of the particulate model during the intervention. The drawing of the learners is shown in figure 4.34 below.

Figure 4. 34 Example of learners' drawing in the class activity on compressing air in a syringe



In the same activity another group of learners as shown in figure 4.35 below wrote the question given by the educator as: *"How can you show that gas particles can be pushed together?"* The learners wrote the steps in point form that the gas is sucked into the syringe firstly. The gas is then squashed and lastly one can let the gas out. The learners seemed to have clearly understood the steps in the compression of gas.

Figure 4. 35 Example of learners' drawing in the activity on compression and expansion of gas in a syringe

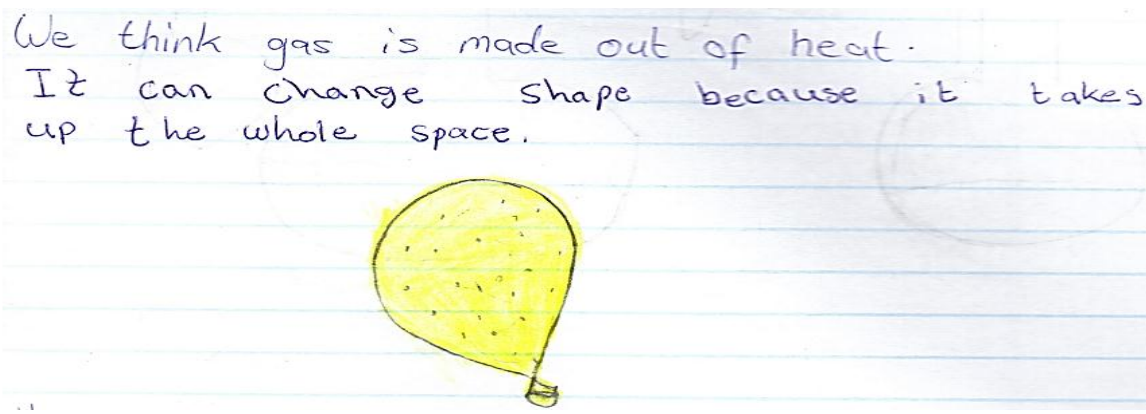


Class activity: What is the shape of air?

In lesson 1 task 2 the aim of the activity was to investigate the shape of air. In this group learners made their drawing and wrote that *"gas is made up of heat"*. Possible reason for this misconception is that learners may be thinking of cooking gas as the only gas they know. So because cooking gas is used for cooking then these learners may be thinking that the gas is the one with heat energy instead of chemical energy.

The learners went on to say that a gas can *"change shape because it takes up the whole shape".* This response is consistent with particulate view of matter in the gaseous phase. In the same drawing these learners represented air by dots, which is consistent with the particulate view of matter. They however also shaded with yellow crayon and it is not clear what the learners meant by the shading. The work done by learners is in figure 4.36 below.

Figure 4. 36 Example of learners' drawing in the class activity on the shape of air



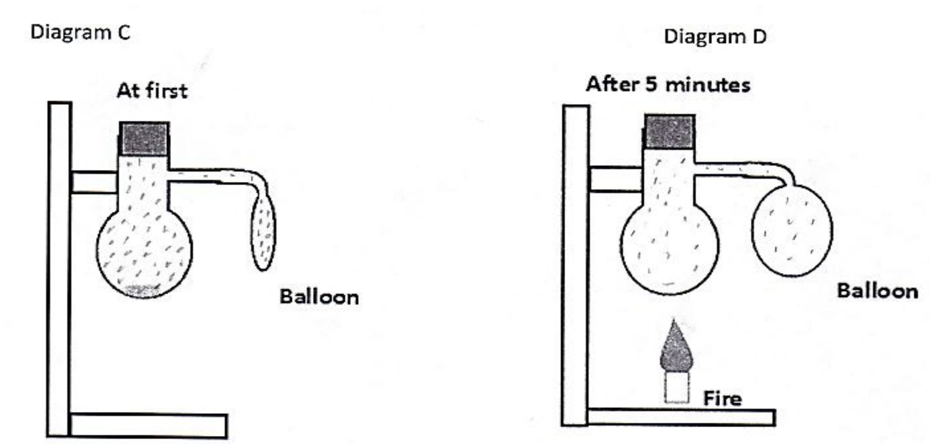
Class activity: Expansion of gases by demonstration

Figure 4.37 below shows the work done by a group of learners during the class activity on expansion of gas demonstration. Learners here made their own drawing and their observations. They said that the *"the stove is making the water"*. This is a misconception that the fire will produce water which then enters the flask above it. They also said *"water is controlling the balloon. So the balloon is growing up"*. This sounds like the animistic view in the sense that water is controlling the balloon.

Figure 4. 37 Example of learners' drawing on expansion of gases by demonstration

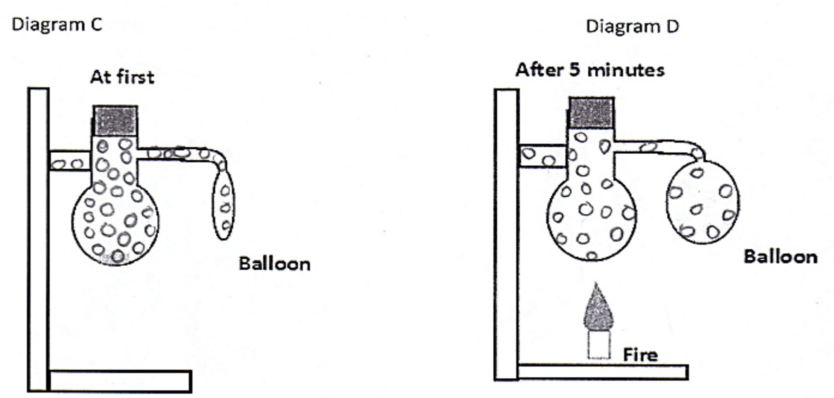
As part of the evaluation stage of the inquiry group figure 4.38 below was used for learners to draw air in the two drawings before and after heating. The diagram below shows the learners' particulate view of matter in the gaseous phase. The dots are more spaced in the second diagram than the first. This is consistent with the particulate view in this case when the volume of the container increases due to expansion of the balloon.

Figure 4. 38 Example of learners' drawing of air in the flask before and after heating (dots).



Other learners also used circles to represent the same particulate view to make their drawings as shown in figure 4.39 below. Just like the 'dot' version in figure 4.38 above, the 'circle' version also has larger spaces in the second diagram than the first as shown in figure 4.39 below.

Figure 4. 39 Example of learners' drawing of air in the flask before and after heating (circles)



4.1.2.2 The lecture group's results during intervention

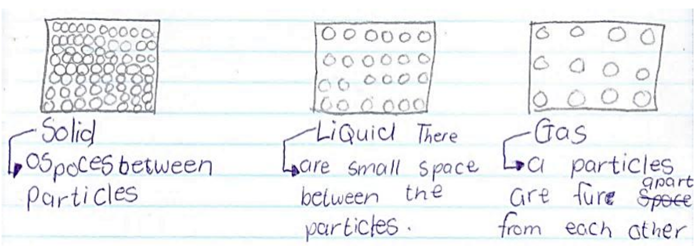
The lecture group was taught using the lecture method. The 5Es model adapted for the lecture approach was used to guide the activities done by the educator and the learner during the lecture method (Bybee, 2010). The adapted method and the expertise of the experienced educators facilitated the delivery of the lecture lessons. Appendix X shows the lesson plans used during the teaching of the class using the lecture method. The lesson plans were also developed following the study by Bybee (2010) where the educator and learners' activities in the lecture method are clearly stated just like in the 5Es IBSE lessons.

In the lecture lessons the learners were not involved in any group work. All content the learners needed to know was presented to them by the experienced educators. Drawings of how air particles could be represented in an empty container, air when pumped, air when sucked out and when air is heated, were all provided to the learners by the experienced educator. The learners were thus presented with all the content they needed to know. The learners were given notes and also wrote these down in their books. The educator wrote many notes and drawings on the board and the learners copied from there. The learners did not ask any questions to seek clarification from the educator. They quietly listened to what the educator was telling them to do and only responded when prompted to do so by the educator. The rest of the time the learners obediently copied all the work presented on the board.

Particulate arrangement of solid, liquid and gas

In the lecture lesson the educator drew the particulate arrangement on the board and gave the learners notes. So learners took down what was given on the board as shown in figure 4.40 below.

Figure 4. 40 Example of a learners' diagram showing the particulate arrangement in solid, liquid and gas copied from the blackboard

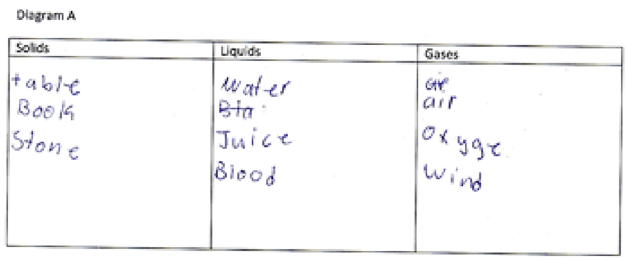


The learners wrote that gas particles *"are far apart"*, liquid has *"small space between the particles"*, and solid has *"zero (0) spaces between particles"*. The learners were taught the particulate view and the arrangement of particles consistent with the PNM.

Examples of solids, liquids and gases

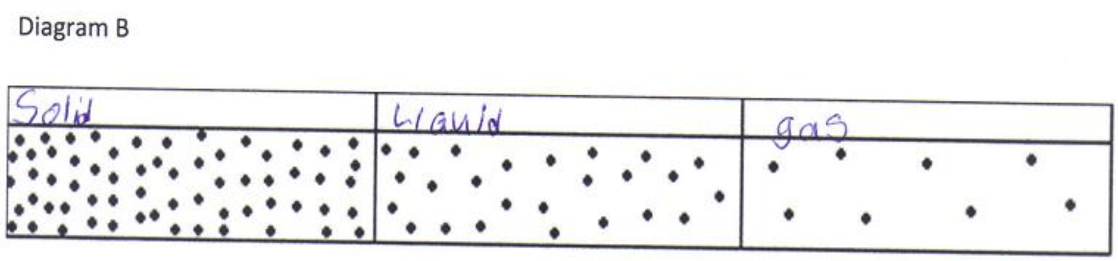
After the first drawings learners were given the diagram in figure 4.41 below. The learners had a task to write three examples of each, i.e. substances in the solid, liquid and gas phase. The examples given by learners are correct. These were ideas presented by learners without the help of the educator.

Figure 4. 41 Example of a learners' diagram showing the examples of substances which are solid, liquid and gas copied from the blackboard



Learners were also given the diagram in figure 4.42 below and asked to label the drawings or representations as solid, liquid or gas according to what they had learned. The responses by learners were correct.

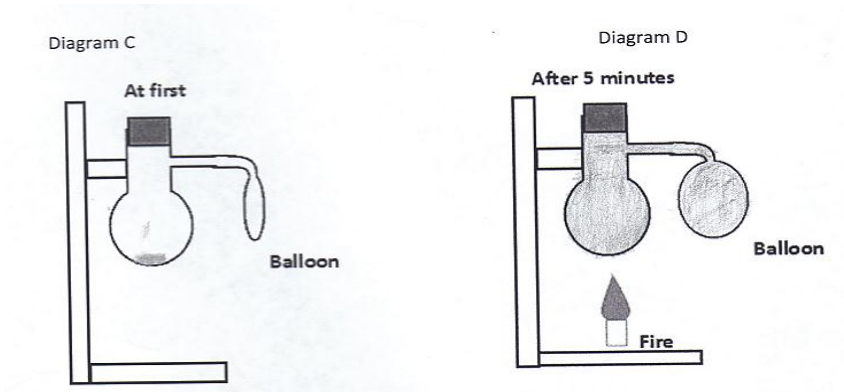
Figure 4. 42 Example of a learners' diagram showing the classification of solid, liquid and gas by particulate arrangement copied from the blackboard



Drawing air in a flask and balloon before and after heating

In conclusion to the lecture lessons the learners were given the diagram in figure 4.43 showing flasks, first one with water at the bottom while the second was empty. The diagram shows that the learners had a continuous view of matter in the gaseous phase. The first diagram is empty except of the water at the bottom, and it is not clear whether the learners did not have enough time to complete the diagram or they considered the flask to be *'empty'*. Such is shown in figure 4.43 below.

Figure 4. 43 Example of a learners' diagram showing the air in flask and balloon before and after heating



4.1.2.3 Comparison of the IBSE teaching approaches by the two experienced educators

As stated earlier on, the inquiry class at school A had 22 learners and the one at school B had 37 learners. Educator 1 taught at school A while educator 2 taught at school B.

Similarities of the teaching approaches

Both educators took long introductions of the first lessons since they did not know the learners' previous knowledge. Also they did not have an idea whether learners knew anything about states of matter. They both carefully guided learners through the 5Es model following the lessons plans on appendix IX. During each group activity they both moved around checking learners in their groups. They both asked probing questions for learners in their groups to assist them develop their responses during the class activities. They also gave learners chances to ask questions and allowed some groups to present their work to the class. Both experienced educators completed their lessons in time and gave conclusions to their lessons.

Differences of the teaching approaches

The learners at school A were easier to control than the learners at school B because of their numbers. Therefore, educator 1 could easily control the class, while educator 2 had difficulties. Educator 2 could not visit all the learners' groups during each activity because the groups were too many. But educator 1 comfortably visited all the groups giving guidance. Educator 1 took more time with each group than educator 2 who tried to rush through in trying to cover all groups, but without success. Subsequently learners at school A got more particulate understanding than learners at school B.

4.1.3 Performance in the post-intervention

In this section is a presentation of the results for the post-test and the second group interviews per class. To start with is an explanation of the findings in the scripts and the interviews for each model. Then at the end is a presentation of the table of results and the graph showing all the models present in the post-test.

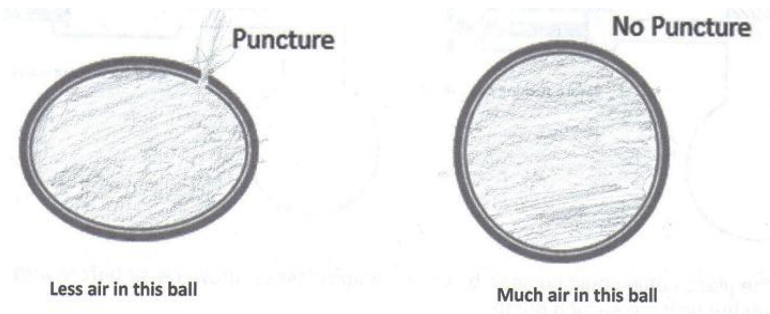
To establish the performance of learners after the intervention, a post-test and second group interviews were administered to the learners. Just like in the pre-test the researcher read and explained all the questions to the learners during the test. But unlike in the pre-test, this time the learners did not ask as many questions. A few questions and comments were, however, noted like *"Do we draw like we did in the other test?"* And other learners would say "*It's the same test?"* and some would say *"This time we are going to beat it"* meaning the learners were expecting to do better in the post-test than the pre-test. After the post-test most learners said they wanted to see their results because they were confident that they did well.

The drawings done by learners in the post-test and the descriptions they gave in the group interviews showed an increase in particulate understanding. All the conceptual models in the pre-test were also observed in the post-test. However, there was a difference in the level of understanding displayed. In the post-test most drawings were done with confidence whether they were continuous or particulate.

4.1.3.1 Continuous conception in the post-test

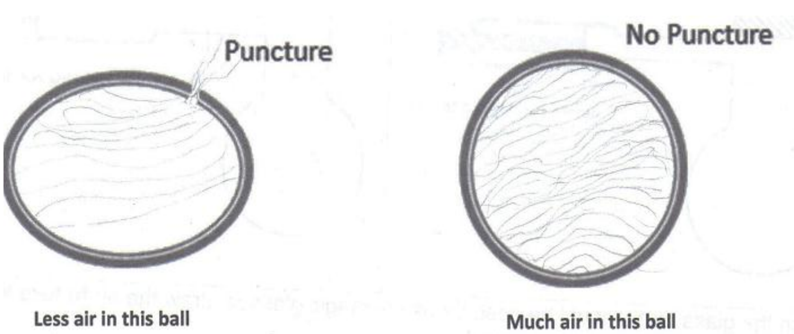
In the post-test the tendency by some learners to represent air by smooth shading persisted. The shading in this case seemed deliberate and to have been drawn with care, showing that the learners had confidence in the accuracy of their drawings. Such drawings are like figure 4.44 below. This shading is consistent with the continuous model observed in the previous study by Nussbaum and Novick (1985).

Figure 4. 44 Example of a learners' diagram showing the smooth shading to represent continuous model in post-test



In other cases, learners also used curved lines shading to represent air. Such drawings are like the one shown in figure 4.45 below. Since it emerged in the first group interview that the curved line shading is the same as smooth shading, here they were interpreted and classified as depicting a continuous model.

Figure 4. 45 Example of a learners' diagram showing the continuous conception after the post-test (curved lines)

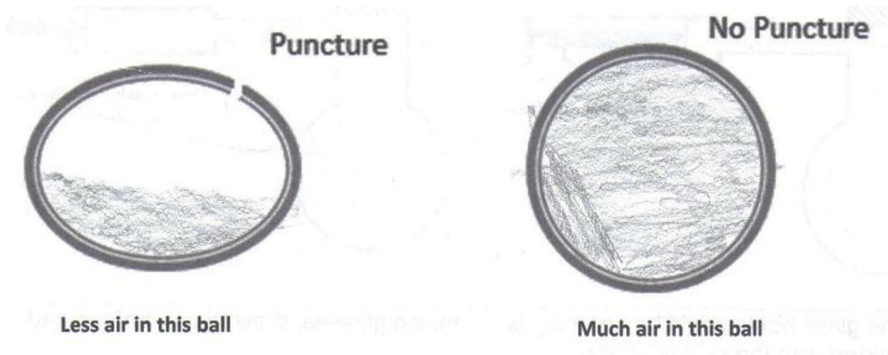


4.1.3.2 Example of a learners' diagram showing the continuous animistic model in the post-test

The continuous animistic model was manifested when smooth shading or curved line shading was used and showing that air settles at the bottom or rises to the top of the container. The group interviews revealed that leaners believed that the top, as in figure

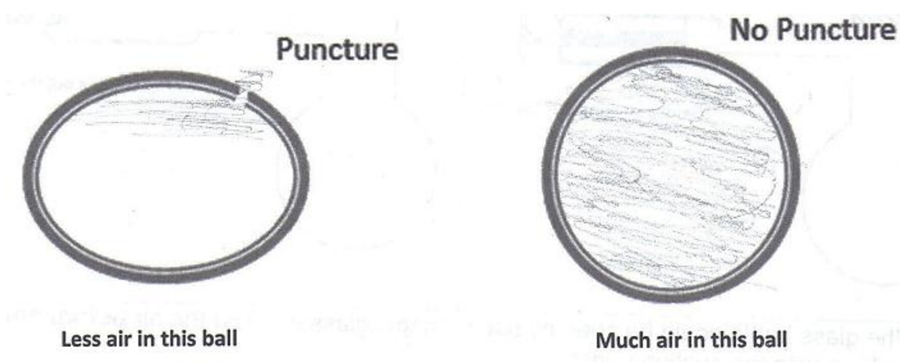
4.46 below, is empty. Learners said, *"There is nothing at the top, air is at the bottom only"*. This seems to imply that learners believed that air is resting at the bottom.

Figure 4. 46 Example of a learners' diagram showing the continuous animistic model (settling down) in the post-test



In other cases, some learners made drawings like figure 4.47 below. This implied that air is only confined at the top and the bottom is empty. This is in line with the natural tendency of air to go up as describe by (Novick & Nussbaum (1985). The learners lack the idea that air will evenly fill the ball with the puncture just as in the ball with much air.

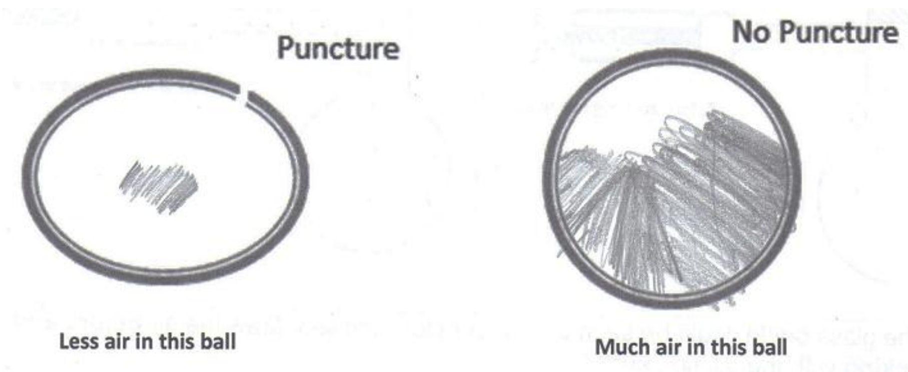
Figure 4. 47 Example of a learners' diagram showing the continuous animistic model (confined at the top) in the post-test



4.1.3.3 Continuous empty model in the post-test

In the continuous empty model, smooth shading or curved lines shading was used. The parts shaded were either at the centre, or side like in figure 4.48 below. There was in this case an unshaded space left out of which learners said *"There is nothing"* during the group interview.

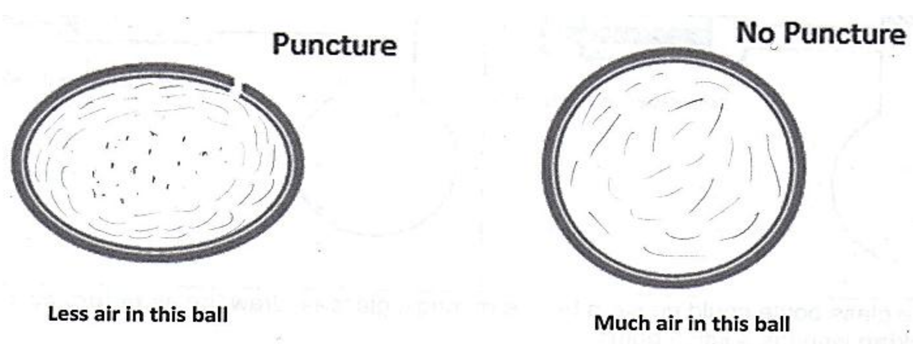
Figure 4. 48 Example of a learners' diagram showing the continuous empty model in the post-test



4.1.3.4 Continuous particulate model in the post-test

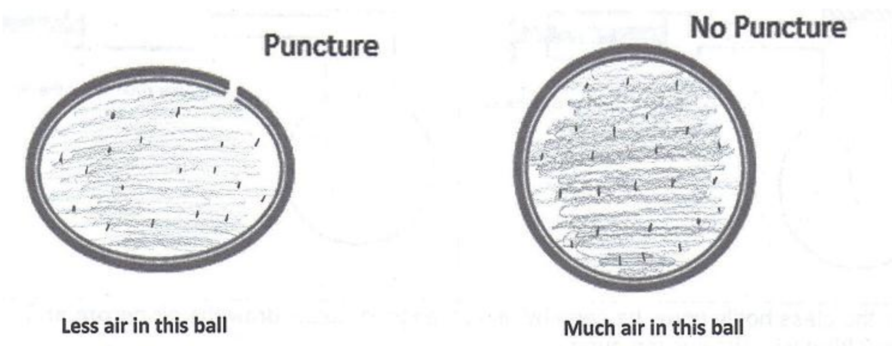
A mixture of particulate and continuous model was also observed. This was a combination of dots and curved lines shading like the one of figure 4.49 below. In this case the dots are around the centre and the curved lines shading around the edges of the ball.

Figure 4. 49 Example of a learners' diagram showing the continuous particulate model in the post-test (curved shading)



In other cases, dots and smooth shading also represented continuous particulate as in figure 4.50 below. Continuous particulate view is a mixture of particulate view and continuous view.

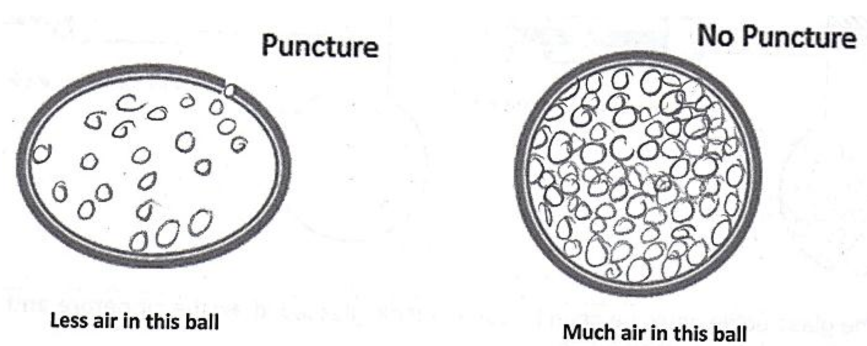
Figure 4. 50 Example of a learners' diagram showing the continuous particulate model in the post-test (smooth shading and dots)



4.1.3.5 Particulate model in the post-test

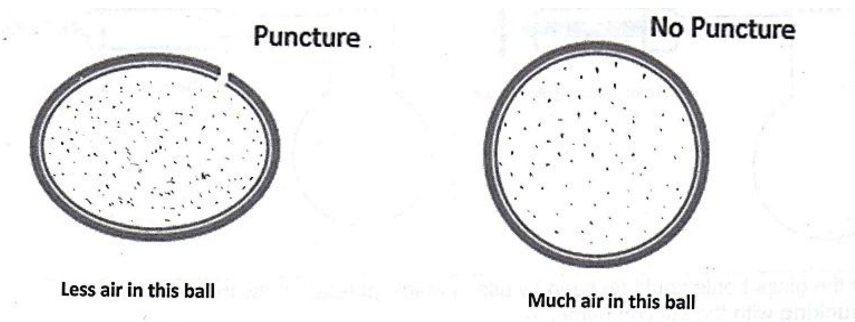
In the post-test particulate model was shown with circles representing particles like in figure 4.51 below. Each circle stands for a particle and the space between the circles represent the vacuum between particles.

Figure 4. 51 Example of a learners' diagram showing the particulate model in the post-intervention (circles)



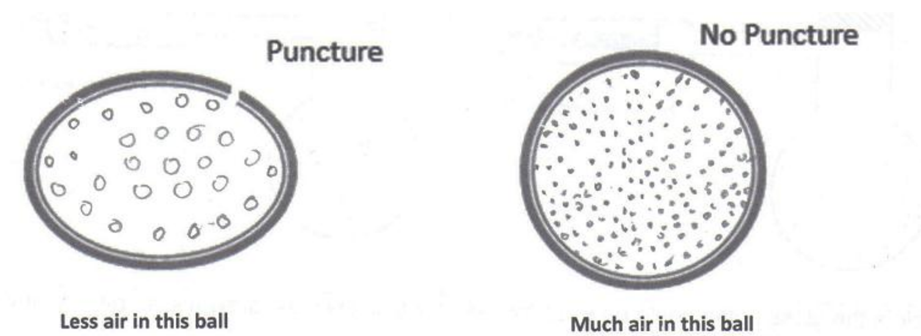
In some cases, particles were also represented by dots like in figure 4.52 below. Instead of circles the learners also used dots to represent particles of gas. This drawing is consistent with the findings by Novick & Nussbaum (1985).

Figure 4. 52 Example of a learners' diagram showing the particulate model in the post-test (dots)



In yet other cases a combination of circles and dots was also used to represent air in the particulate model. An example is as in figure 4.53 below. This drawing stands for particulate view. The difference between the circle or dots diagrams was not clear but it seemed as though the learners used the dots and circles interchangeably.

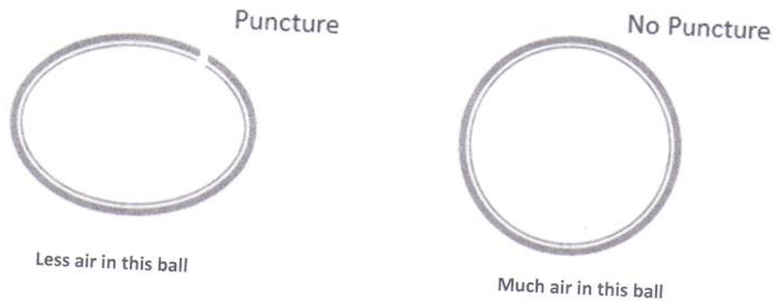
Figure 4. 53 Example of a learners' diagram showing the particulate model in the post-test (dots and circles)



4.1.3.6 Empty model in the post-test

In the post-test a few drawings were like the one shown in figure 4.54 below. In this drawing learners seem not to have drawn anything inside. However, a careful look shows that there is either a faint shading or faint dots drawn by the learner. Maybe the basis of such drawing is that air cannot be seen so the drawing had to be faint.

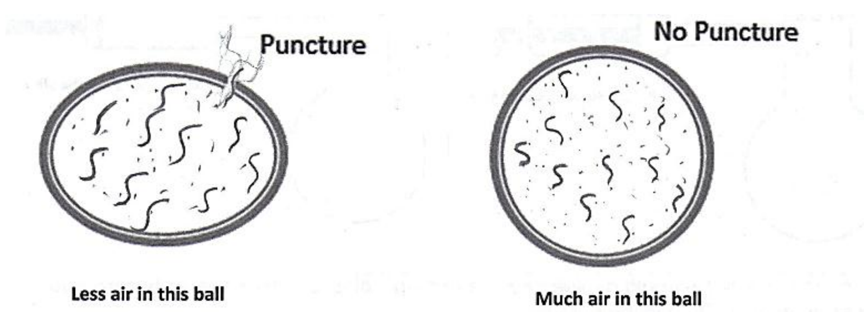
Figure 4. 54 Example of a learners' diagram showing the empty model in the post-test



4.1.3.7 Emerging ideas in the post-test and second group interviews

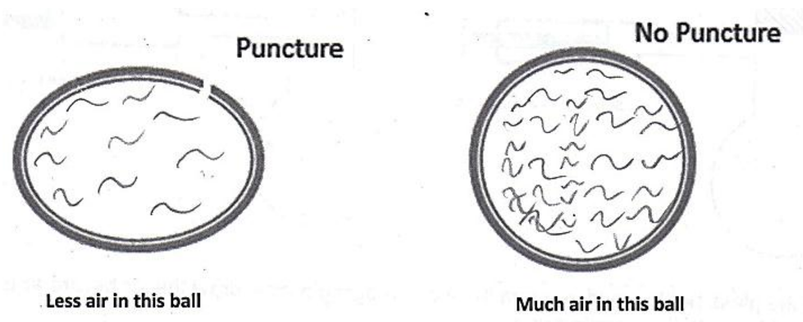
The drawing in figure 4.55 shows some dots indicating particulate view. However together with the dots are S-shaped drawings. It is not clear what the S-shaped objects and dots represent. It is not clear whether the dots and the S-shaped objects stand for the same thing.

Figure 4. 55 Example of a learners' diagram showing the emerging ideas in the post-test (dots and S-shaped objects)



In most cases in the post-test the drawings were similar to those shown in figure 4.56 below. The S-shaped objects which also appeared in the pre-test have also appeared in the post-test but at a lower frequency.

Figure 4. 56 Example of a learners' diagram showing the emerging ideas in the post-test (S-shaped objects)



4.1.3.8 Post-intervention results of inquiry and lecture group at both schools

In the post-intervention in general the percentage of emerging ideas was less than in the pre-intervention. Some of the emerging ideas included statements by learners like *"dots are particles and lines represent air"*. This should be in the continuous particulate view where learners made a mixture of dots and curved lines shading. It appears in this case that while in previous study these type of drawings represented continuous particulate, this statement seems to mean something different. Other quotations are like *"space between dots represent air"*. This quotation just like the previous one leaves one asking, what do dots stand for if not for particles of air? And what would *"particles"* in this case mean? In other cases, learners say *"too much air is represented by circles"* then it might mean that dots may represent less air. Many emerging ideas also appeared in the lecture group in the post-intervention. Such quotations were *"shading means flask is full of air"*, *"shading means there is little space between particles"*, *"curved shading represent particles", "particles are like snakes"*, among others.

Table 4. 2 Post-intervention results for both inquiry and lecture group

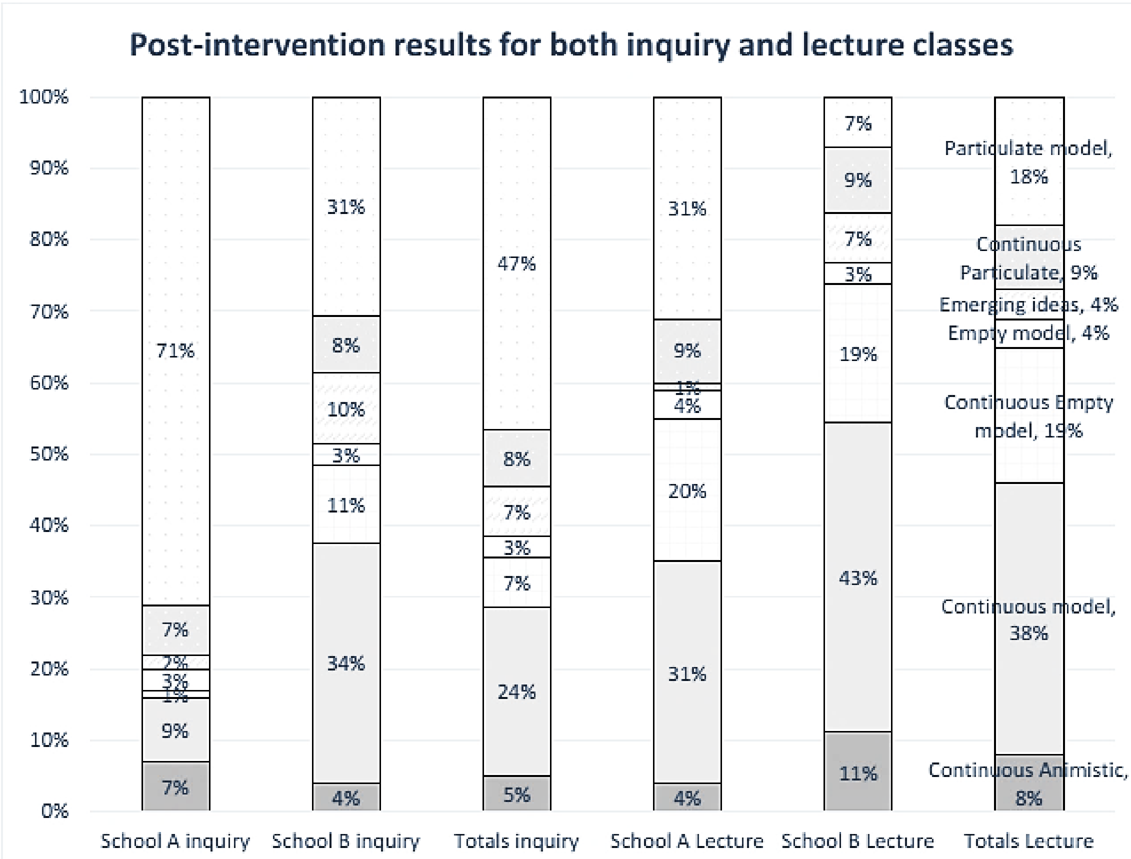
Learner's conception	Inquiry group both schools						Lecture group both schools					
	School A		School B		Totals		School A		School B		Totals	
	Frequency	Percentage %	Frequency	Percentage %	Frequency	Percentage %	Frequency	Percentage %	Frequency	Percentage %	Frequency	Percentage %
Continuous Animistic	15	7	12	4	27	5	10	4	28	11	38	8
Continuous model	21	9	117	34	138	24	70	31	110	43	180	38
Continuous Empty	2	1	36	11	38	7	44	20	49	19	93	19
Empty model	7	3	9	3	16	3	9	4	8	3	17	4
Emerging ideas	5	2	33	10	38	7	3	1	18	7	21	4
Continuous Particulate	16	7	27	8	43	8	20	9	24	9	44	9
Particulate model	160	71	106	31	266	47	69	31	17	7	86	18

4.1.3.9 Inquiry group post-intervention results

As shown in the table 4.2 above and figure 4.57 below, the results for the inquiry class at school A, 71% of the learners held particulate conception while 9% of the learners held continuous conception after instruction using IBSE. 7% of the learners held continuous animistic conception and 7% of the learners held continuous empty model while 1% held continuous particulate was 7%. There were 3% empty models and 2% emerging ideas in the post-test inquiry group at school A.

For the inquiry class at school B 34% of the learners held continuous conception, 31% held particulate conception. The frequency of occurrence for continuous conception and particulate conception were comparable. In the same class 8% of learners held the continuous particulate conception while 4% held the continuous animistic and 11% held the continuous empty model, 3% held the empty model and 10% of the learners had emerging ideas. Possible reasons for the difference observed between lecture classes of these two schools are presented in section 4.1.3.11 below.

Figure 4. 57 Graph of post-intervention results for both inquiry and lecture group

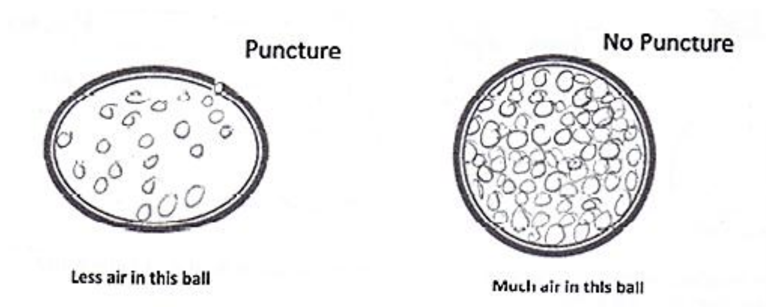


On average for the inquiry group the percentage of learners with particulate conception was 47% and 8% had continuous particulate conception. The percentage of learners with continuous conception in the inquiry group was 24% while the continuous animistic was 5%. The percentage of learners with continuous empty model was 7%, the empty model was 3% and the percentage of emerging ideas was 7% on average in both lecture group in the post-test. More detail is shown in table 4.2 and figure 4.57 above.

The learners responded to the post-test in a more confident way. The learners did not ask rhetoric questions like in the pre-test, instead some learners continued to answer all the questions without waiting for the researcher to read for them. In the final group interviews many learners also could use scientific vocabulary in their responses. They could use concepts and statements like *"particles", "vacuum", "space between"," the gas will expand"*, just to mention a few.

In the post-test many drawings indicated that the learners had adopted the particulate conception of matter in the gaseous phase. The learners could make drawings like the one shown in figure 4.58 below.

Figure 4. 58 Drawing showing particulate conception (circle drawings)



The final group interviews revealed that the circles drawn in the diagram above represent particulate conception. And that there were more particles of air in a ball with much air than the ball with less air as shown in figure 4.58 above. Circles and dots were interchangeably used by learners with particulate conception to represent air particles. In the final group interviews it also emerged that some learners used circles to represent less air and dots to represent more air. This was in agreement with the study by Novick &Nussbaum (1985) which also had dots and circular drawings to represent particulate conception.

The inquiry learners' particulate conception had increased by a large margin in comparison to the initial conception. The particulate conception for the inquiry group had risen to be higher than the continuous conception. The continuous conception decreased greatly after inquiry teaching.

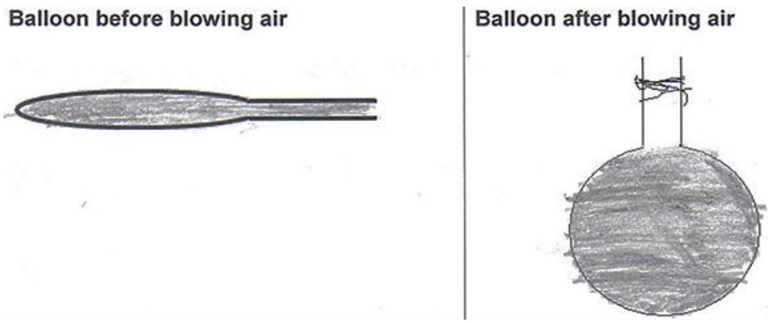
The learners' post-test drawings in the inquiry group were more organized than in the pre-test, and as stated earlier on, the percentage of the particulate conception was higher than the continuous conception. The drawings of learners with particulate conception were well represented with dots or circles. The confusion which was in the pre-test was greatly reduced. In the final group interview the inquiry learners could describe their drawings more explicitly using suitable scientifically acceptable concepts.

4.1.3.10 Lecture group post-intervention results

The post-test results referred to in this paragraph are presented in table 4.2 and figure 4.57 in section 4.1.3.8 above. The percentage of particulate conception at school A was 31% and that for school B it was 7%. This gave an average percentage of 18% particulate conception. The percentage for continuous particulate model was 9% at school A and also 9% at school B. This gave an average of 9% for both schools. The percentage for the continuous animistic model was 4% and 11% for schools A and B respectively. This gave an average of 8% for both schools. The continuous model had 31% and 43% for schools A and B respectively. This made an average of 38% continuous conception in the lecture group. The continuous empty model was 20% and 19% for schools A and B respectively. This resulted in an average of 19% for both lecture group in the post-test. The empty model was at 4% and 3% for school A and B respectively, making 4% average for both lecture group. There was a total of 21 emerging ideas from both classes, making 4% of the responses from learners.

In the lecture group, the percentage of continuous conception in the post-test was still higher than the particulate conception just like in the pre-intervention. However, the percentage of particulate conception had also increased but not to the same extent as in the inquiry group. The learners showed an improved understanding of matter in the gaseous phase than before instruction. The learners' drawings in the lecture group were neater and clearly showing the learners' understanding. An example of a drawing showing continuous conception is as shown in figure 4.59 below.

Figure 4. 59 Drawing showing continuous model



Conceptual change was however not as high as in the inquiry group. I should say conceptual change which occurred in this case showed at least some understanding in the mind of the learner, compared to the understanding of learners before instruction. In figure 4.59 the learner shows continuous conception in the first and the second balloon. In the pre-test, in many cases, the drawings were mixed up as earlier shown in figure 4.2, 4.3 and 4.4 in section 4.1.1.1. The first drawing could show a mixture of conceptions or the second drawing could have a conception different from the first. In contrast to the work done by Novick & Nussbaum (1985), learners in my case study had curved line drawings which also stood for continuous model as revealed in the group interviews. Such drawing is shown in figure 4.59 above.

Summarily the lecture group had a higher percentage of continuous conception than particulate conception. The percentage of particulate conception however, had improved after instruction although not by a larger margin as observed for the inquiry group.

4.1.3.11 Possible reasons for difference in inquiry results in the two schools

Possible reasons for the difference in understanding could be due to the difference in class sizes. The inquiry group at school A had 22 learners while that at school B had 37 learners. It may be that the bigger the class size the more difficult it may have been for learners to perform well in inquiry method. Another possible reason is that the two classes were taught by two different educators. Even if the educators used the same inquiry lesson plans their personal interpretation may have resulted in the different execution of approach. Another possible reason is that as in table 4.1 initially the inquiry group at school A had 6% particulate understanding while that at school B had only 1% particulate understanding. So the initial level of understanding of learners might have helped the school A to perform better.

In conclusion, the drawings by the learners and their explanations in the interviews revealed that learners had an improved understanding of matter as particulate rather than continuous.

4.1.3.12 Results from grade 4 educators' interviews

As indicated in the previous sections two grade 4 educators were interviewed after the intervention. The aim of the interview was to get information from these grade 4 educators on their observations during the intervention. They were expected to give feedback on the activities done in the inquiry group, their perceptions of the learners' reactions, their evaluation of the understanding learners acquired and the effectiveness of the inquiry teaching approach. The following paragraphs are brief discussions of themes that emerged from analysis of educator interview data.

Participation in class

Both educators observed that the participation of learners in class activities was very good. They both commented that *"the children were not passive; they were actively involved in the activities"* as they carried out their class activities. This was in line with previous studies (Abd-El-Khalick, et al., 2004; Anderson, 2002). The educators commented that the learners paid a lot of attention in the class activities. Both educators acknowledged that even the usually passive learners also *"tried to participate and once they made discovery they felt part of the lesson and they were more actively involved in answering questions, which was really, really very encouraging."* This was in agreement with what previous studies identified (Alebiosu, 2005; Bybee, 2010; Oche, 2012; Osborne & Collins, 2001; Poorman, 2002). Thus the class activities done during the inquiry intervention were motivating even the usually passive learners. The class activities provided room for involvement of all learners.

The activities of learners during the intervention were in groups. The learners were doing *"team work and they were more involved"* than usual. The group work done during the inquiry intervention created a *"positive atmosphere"* for learning since learners *"benefited from each other"*. During the inquiry lessons learners were more involved in class activities than in the usual classes. This was observed as the slow learners also became active participants. The learners in their different groups made various discoveries and were very excited at their observations. The educators observed that the learners were excited about working with the apparatus brought to the class which included the syringe and the spray can. The excitement of the learners as observed by the grade 4 educators was in agreement with previous studies (Green, Elliot, & Cummins, 2004; Hewson, 1992; Pringle, 2006).

Understanding of learners

As a result of the high participation of learners during the inquiry group the educators believed that the learners had understood the concepts. During the interview the educators affirmed that the learners *"definitely understood the content. Even the weaker children because there was a number of activities covering the same topic"*. Inquiry approach therefore offered class activities which gave room for all learners to understand the content. One of the educators also commented that *"I personally believe in something done thoroughly using the inquiry method than to rush ahead and the children don't understand the concepts"*. According to the two educators, it was their first time to observe an inquiry lesson. They both initially thought it was not going to work. As learners discussed and did their classwork both educators thought the learners were making noise and usually the educators would shout *"keep quiet"* at the learners. But as the lesson proceeded the educators got impressed and preferred also to use the *"inquiry method than rushing through."* The educators observed that during inquiry the learners *"would be able to understand more clearly"* and benefit from the teaching done in the class. These observations are in agreement with previously done studies (Alkaher & Dolan, 2011; Bybee, 2010; Green, Elliot, & Cummins, 2004).

Performance of learners

The educators believed that because of the active involvement of learners in the inquiry lessons, and the many activities the learners did, that the learners would *"perform better after inquiry"* than the approaches used by the educators previously. The educators believed that the learners had learned more during inquiry than they usually would have learned. This was evidenced by the active participation of all learners including the usually passive learners. The increase in performance of learners may bring solutions to the previously identified, low performance in South African science (Mullis, 2011; Dudu & Vhurumuku, 2012).

Inquiry is a good teaching approach

As evidenced in the interview, the educators understood that *"teaching by inquiry is better than rushing through"* therefore the educators are considering inquiry as a good teaching approach. One of the educators commented that *"if you do you remember"* as an advantage of the inquiry method. The educators stated that learners seem to understand better because they were *"actively engaged"*. Both educators indicated that they were impressed that the learners *"engaged themselves in the content"*, with minimum guidance from the educator (Bybee, 2010; Vygotsky, 1986). Both educators were excited and expressed interest in attempting to teach by inquiry in the future. This was because they observed that IBSE is a good teaching approach and that simple resources were used and the possible outcomes.

Resources used during the inquiry lessons

In connection with the resources used in the inquiry lessons, the educators affirmed that resources used were simple and *"for that particular lesson the resources are easy to find"*. They even said that *"actually the learners could have brought some of the resources themselves as well"* because they were day to day materials learners are familiar with. One of the educators believed that learners would be more excited if they brought the resources themselves. If the school fails to provide the resources *"I myself will bring the resources to the classroom to do the lesson to ensure that it is successful"* declared one of the educators. She said that the resources were easy to find and she would not be troubled to find the resources. The educators believed that the learners would be able to *“answer the inquiry question if they have the resources.”* This was in contradiction with previous observations where resources were considered difficult to find (Kurumeh, Jimin, & Mohammed, 2012).

Learners need guidance during inquiry

One of the educators identified that because of so many activities involved in the inquiry lessons learners may need guidance in inquiry for their safety. This was in agreement with previous observations (Kirschner, Sweller, & Clark, 2006).

More time is required for teaching by inquiry

The educators feel that more time is required to teach by inquiry. For this particular lesson time was well managed but there were challenges. Educators recommend for the department of education to reduce the content so that *“less can be taught more thoroughly using this fantastic method”.* The other educator believed that learners may not have learnt enough and felt more time was required for proper learning to occur. This observation of inquiry method demanding more time was in agreement with the previous observations (Kirschner, Sweller, & Clark, 2006; Kurumeh, Jimin, & Mohammed, 2012).

4.1.4 How instructional approach influenced learners’ understanding

This section shall answer the second research question which sought to understand how instructional approach influenced learners’ understanding. The initial understanding of learners in the lecture group and inquiry group before instruction shall be compared with the understanding of learners after instruction.

The initial understanding of both the lecture group and the inquiry group was comparable at the beginning. After the intervention the learners in the inquiry group had 35% continuous model compared to the 66% in the lecture group. 55% of the learners in the inquiry group had particulate model while the lecture group had only 27%

particulate views. This shows that the inquiry group had a higher particulate view and a lower continuous view than the lecture group after intervention.

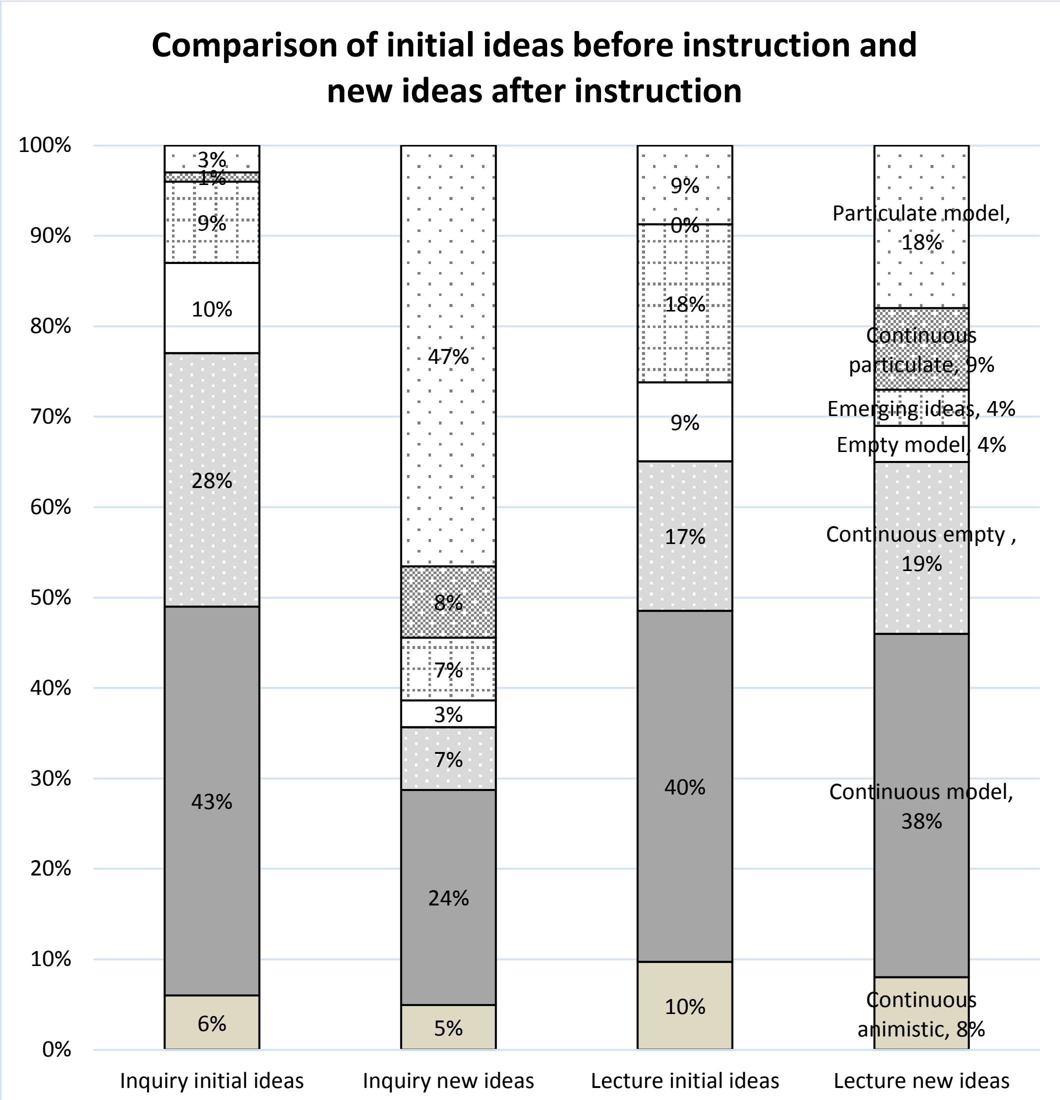
After the post-test the learners participated in the final group interviews. Many learners were interested to participate in the interview. The confidence of learners was so high that those who could not participate in the interview felt bad. During the interview, the learners explained with confidence why they made their drawings. The learners could describe their drawings which showed an improvement in particulate conception sometimes using the word *"particles"* especially in the inquiry group. In the pre-test no learner had ever mentioned the word 'particle'.

More details are shown on the frequency table 4.3 and figure 4.60 below.

Table 4. 3 Comparison of initial ideas and new ideas after instruction

	Inquiry group				**Lecture group**			
	Initial ideas		**New ideas**		**Initial ideas**		**New ideas**	
Learner's conception	**Frequency**	**Percentage %**	**Frequency**	**Percentage %**	**Frequency**	**Percentage %**	**Frequency**	**Percentage %**
Continuous Animistic	37	6	27	5	61	10	38	8
Continuous model	258	43	138	24	237	40	180	38
Continuous Empty model	164	28	38	7	102	17	93	19
Empty model	57	10	16	3	52	9	17	4
Emerging ideas	56	9	38	7	108	18	21	4
Continuous Particulate	5	1	43	8	2	0	44	9
Particulate model	19	3	266	47	52	9	86	18

Figure 4. 60 Graphical comparison of initial ideas and new ideas after instruction



4.1.4.1 Analysis of the post-intervention understanding and retention in the inquiry group

In the inquiry group the pre-intervention results show that 77% of the learners had continuous conception of matter in the gaseous phase, while 4% had particulate conception. 10% of the learners had the empty model while 9% had emerging ideas. After intervention using IBSE method, the new understanding of the learners showed 36% of the learners had continuous conception, 7% had emerging ideas, 3% had the empty model and 55% had particulate conception of matter in the gaseous phase. The researcher tentatively conclude that the teaching approach used, i.e. IBSE may have had an influence in the observed decrease in continuous conception of matter in the gaseous phase from 77% to 36% and a subsequent increase in the particulate conception from 4% before IBSE instruction to 55% after instruction. Therefore, IBSE instruction may have played a part in a decrease in continuous conception and an increase in particulate conception.

The responses of learners in the final interview also indicated that learners had a clear understanding than before instruction. The drawings of the learners were more explicit than in the pre-test and the description of the learners in the interviews showed a higher level of understanding as compared to the first interviews. The learners had an understanding that air is made up of particles and that there is space between the particles. The idea of continuous model was greatly reduced. The learners now had an understanding that a container with less air has larger spaces between particles than a container with much air. The learners also had an understanding that air is evenly distributed throughout the whole container and not confined to the centre, sides, top or bottom of the container. What I observed leads me to believe that young grade 4 learners can work in groups and research on a difficult and abstract topic like matter in gaseous phase with minimum guidance. Learners discussed and came up with different views. The learners were organized in their work and carried out their activities as teams and came out with mostly accurate findings.

Four months after the post-test a follow up test was administered to the learners in both the inquiry group and the lecture group. The aim of the follow up test was to determine the extent of retention by the learners so as to validate the post-intervention results. The learners were not taught again and the learners did not know that they were going to write the test. The test therefore was a surprise to the learners who were thus, not prepared for it. The following table 4.4 and figure 4.61 below show the results of the post-intervention inquiry group as compared to the follow up test in the inquiry group.

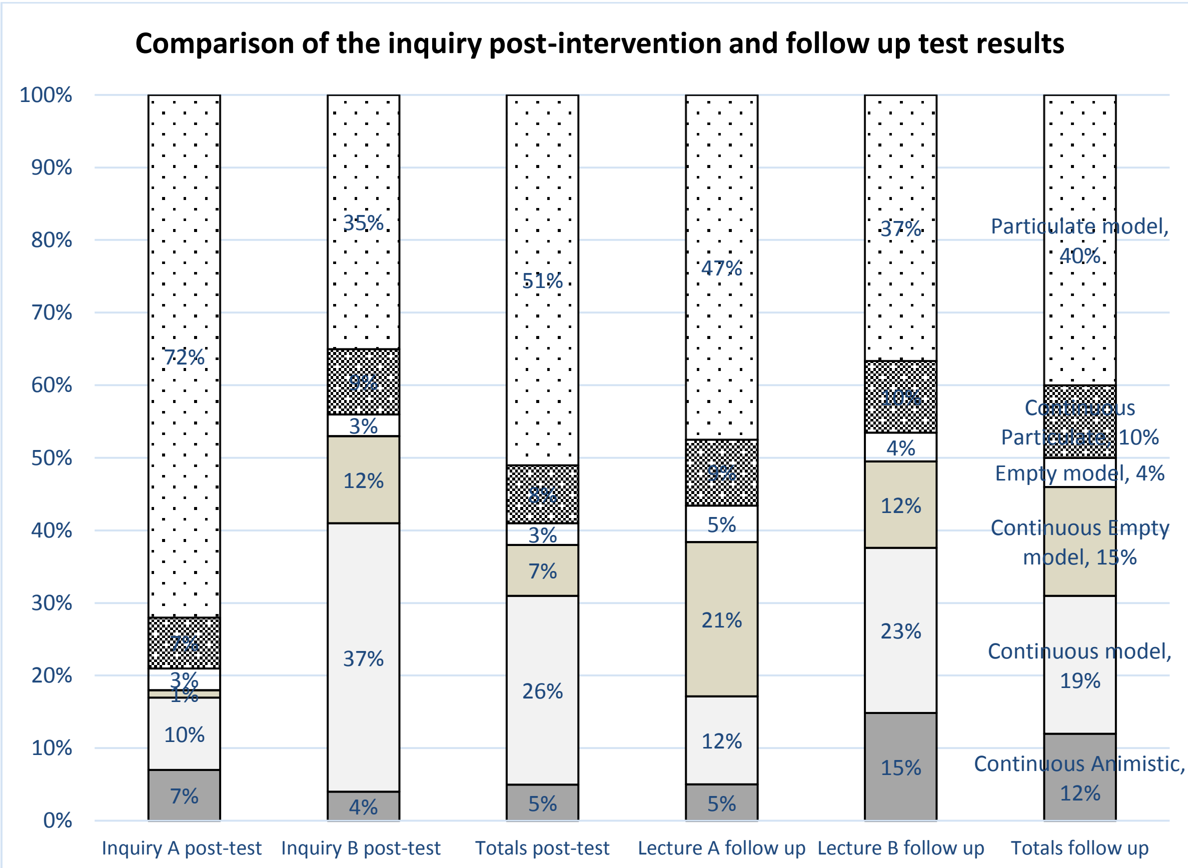
Table 4. 4 Comparison of the inquiry post-intervention and follow up test results

	Inquiry group post-intervention						Inquiry group follow up test					
	School A		School B		Totals		School A		School B		Totals	
Learner's conception	Frequency	Percentage %	Frequency	Percentage %	Frequency	Percentage %	Frequency	Percentage %	Frequency	Percentage %	Frequency	Percentage %
Continuous Animistic	15	7	12	4	27	5	5	5	30	15	35	12
Continuous model	21	9	117	34	138	24	12	12	45	23	57	19
Continuous Empty model	2	1	36	11	38	7	21	21	23	12	44	15
Empty model	7	3	9	3	16	3	5	5	7	4	12	4
Emerging ideas	5	2	33	10	38	7						
Continuous Particulate	16	7	27	8	43	8	9	9	20	10	29	10
Particulate model	160	71	106	31	266	47	46	47	73	37	119	40

In the follow up test the particulate conception had decreased from 47% in the post-test to 40% in the follow up test four months later. The continuous particulate increased from 8% to 10%. The continuous conception had decreased from 24% in the post-test to 19% four months later. The continuous animistic view increased from 5% to 12%. The continuous empty conception also increased from 7% in the post-test to 15% in the follow up test. The empty model increased from 3% to 4%. Overly the particulate conception had slightly decreased while the continuous view had slightly increased. However, the learners had showed considerable retention of their understanding after inquiry instruction. Considering that the learners were not prepared for the test, the results show that the learners had acquired understanding after inquiry instruction.

The gap in table 4.4 above was because in the design of the follow up test new emerging ideas were intentionally not considered. So the table had only emerging ideas in the post-test and none in the follow up test.

Figure 4. 61 Graphical comparison of the inquiry group's post-intervention and follow up test results



4.1.4.2 Analysis of the post-intervention understanding and retention in the lecture group

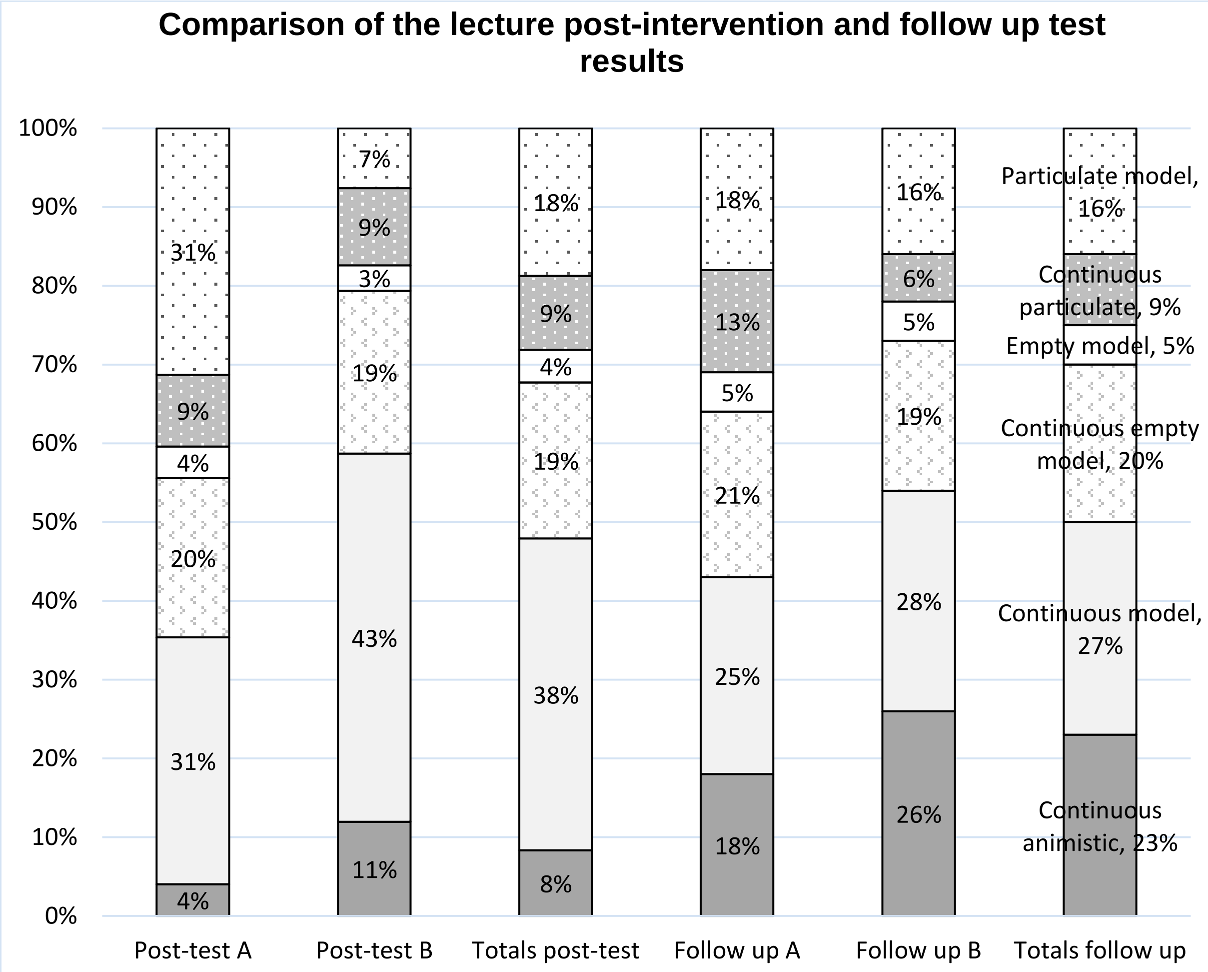
As shown in table 4.5 and figure 4.62 below, in the lecture group 8% of learners had continuous animistic model in the post-intervention compared to 23% in the follow up test. Learners with continuous conception decreased from 38% in the post-intervention to 27% in the follow up test. The continuous empty model increased from 19% in the post-test to 20% in the follow up test while the empty model also increased from 4% to 5%. The continuous particulate remained the same at 9% while the particulate conception decreased from 18% to 16%.

A look at the follow up test results for the lecture group has been tabulated in table 4.5 and also shown in figure 4.62 below.

Table 4. 5 Comparison of the post-intervention and the follow up test in lecture group

	Lecture group post-intervention						**Lecture group follow up test**					
	School A		**School B**		**Totals**		**School A**		**School B**		**Totals**	
	Frequency	**Percentage %**	**Frequency**	**Percentage %**	**Frequency**	**Percentage %**	**Frequency**	**Percentage %**	**Frequency**	**Percentage %**	**Frequency**	**Percentage %**
Continuous Animistic	10	4	28	11	38	8	18	18	40	26	58	23
Continuous model	70	31	110	43	180	38	26	25	44	28	70	27
Continuous Empty model	44	20	49	19	93	19	22	21	30	19	52	20
Empty model	9	4	8	3	17	4	5	5	7	5	12	5
Emerging ideas	3	1	18	7	21	4						
Continuous Particulate	20	9	24	9	44	9	13	13	9	6	22	9
Particulate model	69	31	17	7	86	18	18	18	24	16	42	16

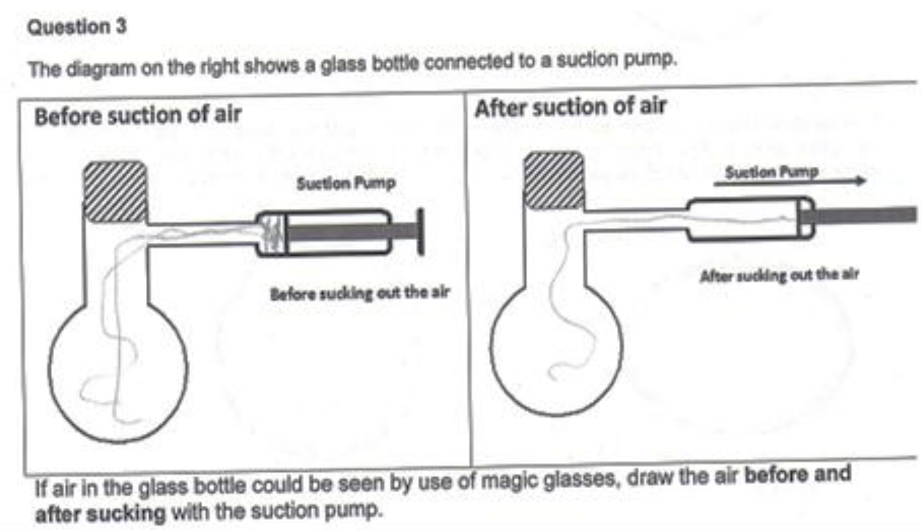
Figure 4. 62 Comparison of the post-intervention and the follow up test in lecture group



The results of the post-intervention in the lecture group were comparable to the results in the follow up test in the same classes. It should be noted that the follow up test was a multiple choice test with drawings provided as distractors while in the post-intervention learners had to make drawings themselves. The results show that some learners in the lecture group had retained particulate conception very well. Though the follow up test was multiple choice, it shows that the learners understood to some extent.

There was a slight improvement in learner particulate understanding after instruction using the lecture method. However, the drawings of the learners showed an improvement in conception, considering that some of the drawings in the pre-test were somehow difficult to interpret. During the lecture group, the learners had been literally told all they needed to know. The experienced educator gave the learners in the lecture group drawing that showed particulate model. This did not, however effect much change on the learners' initial understanding. Therefore, the lecture method may have not effected much change in conceptual understanding. An example of a drawing by a learner after being taught using the lecture method is shown below. It shows that the learner and many other learners had not understood the content.

Figure 4. 63 Example of some learners' drawings after lecture method



An increase in particulate conception of matter in the gaseous phase was observed for learners in both the inquiry and lecture group. However, less increase in particulate conception was observed for the lecture group compared to the inquiry group. A decrease in continuous conception of matter in the gaseous phase was also observed for classes using each of the teaching methods.

In conclusion the particulate understanding of the learners in the lecture group was lower than for the learners in the inquiry group. The continuous conception of learners in the lecture group was higher than in the inquiry group. There was a higher increase in particulate understanding in the classes taught using the inquiry method than in the classes taught using the lecture method. The drawings done by learners taught by the inquiry method show better understanding than the learners taught by the lecture method.

4.2 Summary

In conclusion, many instruments were used to collect data before, during and after the intervention. All data collected was loaded into a software for qualitative data analysis, *Atlas.ti* version 7 for careful coding and categorizing into previously identified models and into other categories emerging in the current study. The initial understanding of learners was established by analysis of the pre-test and the first group interviews. The new understanding of learners was established by analysis of the post-test, the field notes second group interviews and the interviews of the grade 4 educators. The results show that the initial understanding of learners in the lecture group was found to be comparable to that of learners in the lecture group. The new understanding of learners in the inquiry group had a higher particulate view and a lower continuous view of matter than learners in the lecture group.

During the intervention the researcher and the grade educators observed the inquiry lessons. The researcher made field notes of the activities of the learners during the lessons. The analysis of the learners' worksheets revealed that these learners were making considerable progress in acquiring knowledge and understanding in the topic. The learners in the lecture were taking down notes given by the educators. There was very little evidence of improvement in understanding that could be inferred from analysing learners' worksheets in the lecture group.

Grade educators of the inquiry group were interviewed after the intervention. These educators who originally used lecture method in most of their teaching were impressed by the inquiry method and were keen to use inquiry in their future lessons. The educators pointed out some advantages and disadvantages of the inquiry method. Some of the advantages they mentioned were that the learners were excited in the inquiry lessons than they usually do in the lecture method. They also indicated that the resources needed for those particular lessons were readily available and easy to find. The disadvantages they indicated were that more time is needed for inquiry teaching and the more monitoring and control is needed during the inquiry lessons.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter commences with the presentation of the overview of the study. This is followed by a summary of the findings with respect to the research questions. Afterwards follows the conclusions and then finally the limitations of the study with respect to relevant strengths and weaknesses.

5.2 Overview of the study

The aim of the study was to determine how IBSE may influence learner understanding. To investigate this, the topic of nature of matter in the gaseous phase was identified due to its importance in the understanding of the abstract particulate nature of matter in the gaseous phase. This topic is the backbone for all chemistry; therefore, learners' understanding of particulate nature is very important. For this study grade 4 was identified as the most suitable grade in which to conduct the study. The reason for this choice was that the teaching of the nature of matter in the gaseous phase starts in grade 4. Previous studies have reported that conceptual understanding of learners may be influenced incorrectly during formal teaching in class (Areepattamannil, 2012; Blosser, 1987; Pringle, 2006). The assumption, therefore, was that grade 4 learners would be the suitable candidates as they had not yet received any formal education in the topic, and hence have minimum exposure.

To investigate how the IBSE approach influences grade 4 learners' understanding, a qualitative case study was carried out at two schools using two classes per school. A total of 116 learners participated in the pre-test and 20 learners participated in the first group interviews. In the post-test a total of 101 learners participated while 20 learners participated in the second or group interviews. In the follow up test a total of 107 learners participated in the study. The two grade 4 educators of the inquiry group also participated in the interviews for educators.

In this quasi-experimental case study, one class was identified at each school to be taught using the lecture method and these two classes were labelled as the lecture group. Again one class per school was identified for teaching using IBSE and both were identified as the inquiry group. A pre-test was initially administered to all the four participating classes in their normal classroom settings. After each pre-test a group of five learners were randomly selected for the group interviews. The results of the lecture group and the inquiry group were compared to identify the difference, if any, in the initial understanding. The results from the pre-test and the first group interviews provided the information on the initial understanding of learners of the particulate nature of matter in gaseous phase.

Intervention in the form of formal teaching took place for both the lecture group and the inquiry group. The two classes in the lecture group at each school were taught using the lecture method, while the two classes in the inquiry group were taught using the IBSE. The IBSE lessons for both classes were observed by the researcher and the respective grade 4 class educators. This was done so as to observe how IBSE influences the understanding of learners. The experienced educator who taught using IBSE at one school taught using the lecture method at the second school, and vice versa. This was intentionally done to reduce the possibility of bias on the part of the experienced educators. It means if one educator is biased towards one teaching approach for example, then he/she would put in more effort while teaching using one approach than the other.

Soon after the intervention, a post-test was administered to all the four classes in their respective classrooms. After the post-test second group interviews were separately conducted with a randomly selected group of five learners per class. Data obtained from observing the inquiry group was also used as confirming or disconfirming evidence of the new understanding of learners after instruction. The results of the post-test, the second group interviews and the field notes formed part of evidence of the learners' new understanding on the topic of matter in the gaseous phase. The comparison between the initial understanding and the understanding after instruction informed the study about the influence that a teaching approach may have in eliciting learners' understanding of matter in the gaseous phase.

Four months after the post-test was administered, all the four classes were given a follow-up test on the same topic. The aim of the test was to check for the consistency of the post-test results to see if they truly represented and reflected the understanding of the learners or not.

The research questions which guided this study were as follows:

Primary research question:

How does an inquiry-based instructional approach, as compared to a lecture approach, influence grade 4 learners' understanding of the PNM in the gaseous phase?

Secondary research questions:

In order to address this question, the following sub-research questions were explored:

1. What initial understanding do grade 4 learners have on the topic 'the particulate nature of matter in the gaseous phase'?
2. What level of understanding do learners in the inquiry and lecture groups have after being taught with IBSE and lecture methods respectively?

Qualitative data obtained from the pre-tests, post-tests, first and second group interviews, observations of learners in the inquiry lessons and the interview responses of the grade educators were all loaded onto *Atlas.ti* for data analysis. Data was coded by the researcher and also by my supervisor for inter-coder reliability.

5.3 Summary of the findings

The previous paragraphs were a presentation of the overview of the study. The following discussion will focus on the results obtained as well as how these results were used to answer the two secondary research questions thereby providing an answer to the primary research question.

Sub-research question 1: What initial understanding do grade 4 learners have on the topic 'the particulate nature of matter in the gaseous phase'?

The aim of this research question was to identify the initial understanding of both the inquiry group and the lecture group before intervention. To achieve this, both groups were given the same pre-test and a group of five learners from each class was interviewed after writing the test.

All the data from the scripts of the learners in the pre-test and the first group interviews of the four classes were coded into a priori and emerging mental models using *Atlas.ti* and the following table of results was generated.

Table 5. 1 Table showing initial understanding of both the inquiry and lecture groups

	Inquiry group		**Lecture group**	
Learner's conception	**Frequency**	**Percentage %**	**Frequency**	**Percentage %**
Continuous Animistic	37	6	61	10
Continuous model	258	43	237	39
Continuous Empty model	164	28	102	17
Empty model	57	10	52	8
Emerging ideas	56	9	108	18
Continuous Particulate	5	1	2	0
Particulate model	19	3	52	8

In the inquiry group 3% of learners' ideas showed particulate view and 1% showed continuous particulate conception. In the lecture group 8% of the learners had particulate view and nil continuous particulate. The results show that the lecture group had a slightly higher percentage of particulate view understanding than the inquiry group. The inquiry group had 9% emerging ideas while the lecture group had 18% emerging ideas. The lecture group therefore had a higher percentage of emerging ideas than the inquiry group. Generally, both groups had comparable particulate understanding to begin with.

The continuous view which includes the continuous animistic model, the continuous model and the continuous empty model had a total of 77% in the inquiry group and a total of 66% in the lecture group. The inquiry group therefore had more continuous view than the lecture group. The empty model was 10% in the inquiry group and 9% in the lecture group. This empty model seems to have the same percentage value in the lecture and inquiry group.

Overly the results indicate that the initial view of both the lecture group and the inquiry group was mainly that of the continuous view of matter in the gaseous phase than the particulate view. Learners in both the inquiry group and the lecture group made shadings, mainly smooth shadings and curved line shadings to represent continuous conception. The particulate view was not a common view especially in the inquiry group where the particulate view was as low as 3%. Learners in this case made dots or circles to represent the particulate view.

Another observation is that the percentage of continuous view for the inquiry group and the lecture group was almost the same. This means that before instruction both groups started at almost the same level of conception. That slight difference which is there shows that the inquiry group had a higher continuous view than the lecture group and that the inquiry group had a lower particulate view than the lecture group.

Sub-research question 2: What level of understanding do learners in the inquiry and lecture groups have after being taught with IBSE and lecture methods respectively?

The second sub-research question looked at the new understanding of learners after instruction. This means that the aim was to view the understanding of learners in the inquiry group after IBSE instruction and the understanding of learners in the lecture group after instruction using the lecture method.

The post-test scripts were scanned and loaded into *Atlas.ti* together with the transcriptions of the second group interviews and the field notes of my observations in the lecture group. The data analysis of these documents after coding and categorizing provided information about the new understanding of learners after instruction. The summary of these results is shown in table 5.2 below.

Table 5. 2 Table showing new understanding of both inquiry and lecture groups

	Inquiry group			**Lecture group**		
Learner's conception	**Initial ideas**	**New ideas**	**Change**	**Initial ideas**	**New ideas**	**Change**
Continuous Animistic	6%	5%	-1%	10%	8%	-2%
Continuous model	43%	24%	-19%	39%	38%	-1%
Continuous Empty model	28%	7%	-14%	17%	19%	+2%
Empty model	10%	3%	-7%	9%	4%	-5%
Emerging ideas	9%	7%	-2%	18%	4%	-16%
Continuous Particulate	1%	8%	+7%	0%	9%	+9%
Particulate model	3%	47%	+44%	9%	18%	+9%

The combination of the continuous animistic, the continuous model and the continuous empty models are referred to as the 'continuous view', while the continuous particulate and particulate models are referred to as the 'particulate view'. The continuous views in the post-test had a total of 36% responses in the inquiry group and 65% in the lecture group. This means that the lecture group had more continuous view than the inquiry group. The percentage of continuous view in the lecture group is almost double the continuous view in the inquiry group after instruction. The particulate view in the inquiry group was 55% and in the lecture group the particulate view was 27%. The particulate view in the inquiry group is double as much as in the lecture group. Thus after instruction, the inquiry group had a lower percentage of the continuous view and a higher percentage of the particulate view than the lecture group.

The empty model in the inquiry group was 3% and in the lecture group was 4%. The percentage of emerging ideas was 7% in the inquiry group and 4% in the lecture group. In general, the percentages of the empty model and the emerging ideas was almost the same. In other words, there seems to be not much difference in the percentages of the empty model in the inquiry group as compared to the lecture group. Again the percentage of emerging ideas in the inquiry group was almost the same as in the lecture group.

The drawings made by learners and their responses in the group interviews showed that learners had an improved understanding after instruction in the inquiry group. Even when the learners' drawings were those reflecting a continuous view, the drawings they made in the post-test were clearer, neater and much easier to classify than in the pre-test.

In summary, the ideas or conceptual models of learners consisted more of the particulate view after instruction using IBSE than when the lecture method was used. Also, fewer instances of ideas indicative of a continuous view were observed after instruction using IBSE than when using the lecture method. Table 5.2 gives an overall view of the initial and new understanding of learners as signified by the frequencies of occurrences of mental models observed before and after instruction. The percentage change in the level of understanding in the inquiry group was more than in the lecture group. In the particulate view, there was a total of +51% increase in the inquiry group compared to +18% in the lecture group. This means that there was more improvement in particulate understanding after instruction using the IBSE than after using the lecture method. Therefore, the IBSE could be assumed to have been more effective in eliciting particulate understanding than the lecture method in this study.

The change in continuous conception after instruction was -34% in the inquiry group and -2% in the lecture group. The results show that the IBSE method resulted in a greater percentage reduction in continuous understanding than the lecture method. The inquiry method resulted in the greater reduction in the scientifically unacceptable continuous model and a greater increase in the scientifically acceptable particulate conception. Thus IBSE was found to be more effective in the development of favourable conception than the lecture method.

Another observation was that using the lecture method the change in continuous conception was only -2%. This seems to show that the lecture method may not be very effective in eliciting meaningful conceptual change. It seems to show that learners almost retained their initial conception even after instruction. On the other hand, the inquiry method managed to effect a change of -34% in continuous conception. The improvement after IBSE seems to show that inquiry is more effective than the lecture method.

The educators' observations revealed that learners were actively participating in various class activities in the inquiry class. The learners were, therefore, very motivated and excited to participate in class activities during the IBSE lessons. The educators also noted that the usually passive learners were also actively involved during IBSE lessons and appeared to be enjoying the lesson with their classmates. Because of this active participation in various class activities, the educators anticipated that the learners understood the particulate model. They also anticipated high performance of the learners. The educators were confident of being able to find resources for similar IBSE lessons because the resources are simple and easy to find. They were also confident to teach using IBSE in their future lessons. The educators observed that the duration of the lesson was just like that for the lecture class.

Table 5.4 below shows the comparison of the post-test results and the follow up test results. The particulate conception had, after instruction, decreased by 7% in the inquiry group and by 2% in the lecture class. The continuous particulate increased by 2% in the inquiry group and there was no change in the lecture class. The empty model increased by 1% in both the inquiry and the lecture groups. The continuous empty model increased by 8% in the inquiry group and by 1% in the lecture group. The continuous model decreased by 5% and by 11% in the inquiry group and the lecture group respectively. There was no change in the continuous animistic in the inquiry group. In the lecture group the continuous animistic increased by 15%.

The follow up test which was administered four months after the intervention yielded results that show high levels of retention of the particulate model especially in the inquiry group. This seem to suggest that the IBSE approach may have resulted in learners getting stable particulate conception.

Table 5. 3 Results of the follow up test compared to post-test

Learner conception	Inquiry group			Lecture group		
	Post-test	Follow up	Change	Post-test	Follow up	Change
Continuous animistic	5%	5%	0%	8%	23%	+15%
Continuous	24%	19%	-5%	38%	27%	-11%
Continuous empty	7%	15%	+8%	19%	20%	+1%
Empty	3%	4%	+1%	4%	5%	+1%
Continuous particulate	8%	10%	+2%	9%	9%	0%
Particulate	47%	40%	-7%	18%	16%	-2%

5.4 Conclusions

The educational implications of this study may be summarized as follows:

As revealed in this study the inquiry method was observed to have been more effective than the lecture method in eliciting improved particulate conception and reducing continuous conception. For teaching using IBSE more time is needed because of the many activities learners do during IBSE. However, giving IBSE enough time and guidance, learners may understand better. Preparing an inquiry lesson and teaching young children by inquiry requires a lot of effort and planning. However, the outcome of IBSE may be worth the effort invested. On the other hand, a lecture method may take less effort to prepare but fail to reach the desired learning outcomes.

Based on the above observations, IBSE seems to be a commendable teaching approach especially for teaching abstract topics like particulate nature of matter. The inquiry approach may have been tried in some parts of the world and may have failed to yield good results or otherwise, but this study has yielded good results (Areepattamannil, 2012). Therefore, IBSE is recommended for use in teaching, for in-service training of educators, and also for pre-service training of educators.

Educators need to be aware of the fact that some learners come to school with misconceptions which can hinder successful learning. It is possible for educators to assume that learning has taken place after each lesson, but learning should rather be measured by the amount of understanding that has been developed in the minds of the learners.

The interview for learners provided an in-depth revelation about children's drawings which show the ideas children have about matter. Therefore, giving an audience to learners may provide useful information about their understanding of the concepts they are studying. Most mental models identified in the participants of the current study are similar to mental models observed in previous studies done in other countries (Novick & Nussbaum, 1981). This seems to show that children's ideas may be similar worldwide, such as, the continuous model, continuous animistic, continuous empty, the empty model, the particulate model and the continuous particulate model.

In addition to those previously identified models, there were other models which emerged in the current study. These models are classified in the current study as emerging models in section 4.2.1.8 and section 4.2.3.7 observed during the pre and post-intervention stages respectively.

Unique to this study, a follow-up test four months after data collection was administered to establish the consistency of the method of data collection. The follow up test instrument was a multiple choice question test with responses of learners chosen from the pre-test and post-test used as distractors. The use of the follow-up test also enabled the identification of learners' retention of understanding four months after the intervention. Previous studies did not seek retention of understanding. Further follow up studies may be done with the participants of this study to assess the impact of the teaching approach used. Similar studies could also be done to assess the impact of other individual or combined teaching approaches in effecting conceptual change. Studies similar to this may also be done tracing the progress of individual learners from the pre-test till the follow up, and studies could also be done in the proceeding grades.

This study also provided the views of educators who observed the inquiry lessons. The educators revealed that they were not aware of the inquiry teaching approach, but in a short time they were both interested in implementing inquiry in their future lessons. Therefore, it may be recommended that education stakeholders conduct in-service training to educators to familiarize them with modern teaching innovations such as the IBSE, to improve learner understanding.

Although the pre-test and post-test instruments were developed by adapting items presented in the book of Novick and Nussbaum (1985), considering the context in which the study took place meant that the test instruments had to be modified accordingly prior to being used for data collection.

5.5 Limitations of the study

The study has certain limitations which should be taken into consideration when interpreting the results. The limitations concern the following:

The limitation of a case study design is that data obtained cannot be generalized, i.e. findings based on data from this study cannot be generalized to any population group.

The IBSE may have yielded the desirable particulate model but the researcher cannot ascertain if no other factors may have played a part, such as, if the classes were grouped according to ability, and by coincidence the IBSE may have been the better class. This is unlikely since the learners had similar initial understanding before intervention.

Keeping the identities of the participants anonymous by not asking the learners to write their names down in their test scripts made it difficult to trace how conceptual understanding of individual learners changed as depicted by their drawings or interview responses before and after instruction. This could perhaps be the aim of future research.

Furthermore, the research may be done with schools from different social setting or backgrounds, to identify the influence of IBSE and lecture method on learner understanding. The subject content may be on PNM or any other topic and subject.

REFERENCES

Abd-El Khalick F. & Akerson V. L. (2004). Learning as Conceptual Change: Factors that Mediate the Development of Pre-servics Elementary Educators' Views of Nature of Science. *Science Education*, 785-810.

Abd-El Khalick, F., Boujaoude, S., Duschl, R., Lederman, N. G., Mamluk-Naaman, R., Hofstein, A., & Taun, H. (2004). Inquiry in Science Education: International Perspectives. *Science Education, 88*, 397-419.

Abraham, M. R., Williamson, V. M., & Westbrook, S. L. (1994). A Cross-age Study of the Understanding of Five Chemistry Concepts. *Journal of Research in Science Teaching 31(2)*, 147-165.

Adams, J. D., & Mabusela, M. S. (2013). Employing role-play in teaching and learning: A case of higher education. *South African Journal of higher education 27(3)*, 489-500.

Alebiosu, K. A. (2005). Utilising Selected Informal Science Experiences to Teach Science in Inquiry-centered Nigerian Classrooms. *African Education Review 2(1)*, 109-117.

Alemu, B., & Schulze, S. (2012). Active learning approaches in mathematics education at universities in Ethiopia: the discrepancies between policy and practice. *Acta Academia 44(2)*, 136-154.

Alkaher, I., & Dolan, E. (2011). Instructors' Decisions that Intergrate Inquiry Teaching into Undergraduate Courses: How Do I Make This Fit? *International Journal for the Scholarship of Teaching and Learning Vol 5 No.2*, 9.

Allers, N. (2007). Teaching Pre-medical Sciences to large groups: matching teaching and learning styles in higher education. *Acta Academia 39(3)*, 183-199.

American Association for the Advancement of Science. (2000). *Inquiry into Inquiry Learning and Teaching in Science.* Washington, DC: National Academy.

Anderson, A., & Krathwohl, D. (2000). *A Taxonomy for Learning, Teaching and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives (Second Edition).* New York: Allyn and Bacon.

Anderson, R. D. (2002). Reforming Science Teaching: What Research Says About Inquiry. *Journal of Science Teacher Education 13*, 1-12.

Areepattamannil, S. (2012). The Effects of Inquiry-Based Science Instruction on Science Achievement and Interest in Science: Evidence from Qatar. *Journal of Educational Research, 105*, 134-146.

Avery, L. M., & Meyer, D. Z. (2012). Teaching Science as Science is Practised: Opportunities and Limits for Enhancing Pre-service Elementary Educators' Self Efficacy for Science and Science Teaching. *School Science and Mathematics Journal, 112*, 395-409.

Ayas, A., Ozmen, H., & Calik, M. (2010). Students' Conceptions of the Particulate Naature of Matter at Secondary and Tertiary level. *International Journal of Science and Mathematics Education, 8(1)*, 165-184.

Ayas, A., Özmen, H., & Çalik, M. (2010). Students' conceptions of the particulate nature of matter at secondary and tertiary level. *International Journal of Science and Mathematics Education, 8*, 165 – 184.

Barke, H. D., Hazari, A., & Yitbarek, S. (2009). Chapter 2: Students' Misconceptions and How to Overcome Them. In R. S. Cole, *Misconceptions in Chemistry: Addressing Perceptions in Chemical Education* (pp. 21-36). Berlin: Springler-Verlag.

Bloom, B. S. (1956). *Taxonomy of Education Objective, Handbook 1: Cognitive Domain.* New York: David Mckay Co Inc.

Blosser, P. E. (1987). Science Misconceptions Research and Some Implications for the Teaching of Science to Elementary School Students. *ERIC/SMEAC Science Education Digest No.1*.

Blumberg, P. (2008). *Developing Learner-Centered Teachers: A Practical Guide for Faculty.* San Francisco: Jossy-Bass.

Bolat, M., & Sozen, M. (2011). Determining the Misconceptions of Primary School Learners Related to Sound Transmission Through Drawing. *Procedia Social Behavioral Sciences,1*, 1060-1066.

Boz, Y. (2006). Turkish Pupils' Conception of the Particulate Nature of Matter. *Journal of Science Education and Technology, 15*, 203-213.

Braun, V., & Clarke, V. (2006). Using Thematic Analysis in Psychology. *Qualitative Research in Psychology; 3*, 77-101.

Bybee, R. W. (1997). *Achieving Scientific Literacy: From Purposes to Practice.* Portsmouth, NH: Heinemann.

Bybee, R. W. (2010). *The Teaching of Science: 21st Century Perspective.* Arlington, VA: NTSA Press.

Cakici, Y., & Yavuz, G. (2012). The Effect of Constructivist Science Teaching on 4th Grade Students' Understanding of Matter. *Asia-Pacific Forum on Science Learning and Teaching,11, Available on http://www.ied.edu.hk/apfslt/v11 issue2/cakici/cakici7.htm*.

Cantrell, D. C. (2001). *Alternative Paradigms in Environmental Educational Research: The Interpretive Perspective [online]*. Retrieved from http://edu.eluth.ca/ciccte/naceer.pgs/alternate/pubfiles/08.Cantrell.fin.htm

Coetzee, A., & Imenda, S. I. (2012). Effects of outcomes-based education and traditional lecture approaches in overcoming alternative conceptions in physics. *African Journal of Research in MST Education 16(2)*, 145-147.

De Vos, W., & Verdonk, A. H. (1996). The Particulate Nature of Matter in Science Education. *Journal of Research in Science Education, 33(6)*, 657-664.

Department of Basic Education. (2012). *Grades 4-6 Natural Sciences and Technology, National Curriculum Statement-CAPS. In Department of Education (Ed).* Pretoria: Government Printing Works.

Dudu, W. T., & Vhurumuku, E. (2012). Educators' Practices of Inquiry When Teaching Investigations: A Case Study. *Journal of Science Teacher Education, 23*, 579-600.

Earp, J. A., & Ennett, S. T. (1991). Conceptual Models for Health Education Research and Practice. *Health Education Research, 6(2)*, 163-171.

Ebersohn, L., Eloff, I., & Ferreira, R. (2011). First Steps in Action Research. In K. Maree, *First Steps in Research* (pp. 124-141). Pretoria: Van Schaik Publishers.

Fereday, J., & Muir-Cochrane, E. (2006). Demonstrating Rigor Using Thematic Analysis: A Hybrid Approach of Inductive and Deductive Coding and Theme Development. *International Journal of Qualitative Methods 5 (1)*.

Furtak, E. M., Seidel, T., Iverson, H., & Briggss, D. C. (2012). Experimental and Quasi-Experimental Studies of Inquiry-Based Teaching: A Meta-Analysis. *Review of Educational Research, 82*, 300-329.

Goldkuhl, G. (2012). Pragmatism vs Interpretivism in Qualitative Information Systems Research. *European Journal of information Systems, (21), 2*, 135-146.

Green, W. J., Elliot, C., & Cummins, R. H. (2004). "Prompted" Inquiry-Based Learning in the Introductory Chemistry Laboratory. *Journal of Chemical Education, 81*, 239-241.

Guba, E. G., & Lincoln, Y. S. (1994). Competing Paradigms in Qualitative Research. In N. K. Denzin, & Y. S. Lincoln, *Handbook of Qualitative Research* (pp. 105-117). London: Sage.

Haidar, A. H. (1997). Prospective Chemistry Teachers' Conceptions of the Conservation of Matter and Related Concepts. *Journal of Research in Science Teaching, 34(2)*, 181-197.

Haidar, A. H., & Abraham, M. R. (1991). A comparison of Applied and Theoretical Knowledge of Concepts Based on the Particulate Nature of Matter. *Journal of Research in Science Teaching 28(10)*, 919-938.

Harvey, S., & Daniels, H. (2009). *Inquiry Approach Versus Coverage Approach: Comprehension and Collaboration.* Portmouth, NH: Heinemann.

Hewson, P. W. (1992). *Conceptual Change in Science Teaching and Teacher Education. National Centre for Educational Research, Documentation Assessment.* Madrid.

Hofstein, A., & Lunetta, V. N. (2004). The Laboratory in Science Education. Foundation for the 21st century. *Science Education, 88*, 28-54.

Hrepic, Z., Zollman, D., & Rebello, S. (2010). Identify Learners' Mental Models of Sound Propagation: The Role of Conceptual Blending in Understanding Conceptual Change. *Physics Education Research Conference.* Boise, ID.

Johnstone, A. H. (2000). Teaching of chemistry – Logical or psychological? *Chemistry Education Research and Practice in Europe, 1*, 9 – 15.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-based, Experiential, and Inquiry-Based Teaching. *Educational Psychologist, 41:2*, 75-86.

Kolkhorst, F. W., Mason, C. L., Dipasquale, D. M., Patterson, P., & Buono, M. J. (2001). An Inquiry-based Learning Model for an Exercise Physiology Laboratory Course. *Advanced Physiology Education, 25*, 45-50.

Kompa, J. S. (2012). *Key Disadvantages of Teacher-centered Learning.* Liverpool: Available on http://joanakompa.com/disadvantages of teacher-centered learning.

Kurumeh, M. S., Jimin, N., & Mohammed, A. S. (2012). Enhancing Senior Secondary Students' Achievement in Algebra Using Inquiry Method of Teaching in Onitsha Educational Zone of Anambra State, Nigeria. *Journal of Emerging Trends in Educational Research and Policy Studies 3(6)*, 863-868.

Laugksch, R. C. (2000). Scientific Literacy: A Conceptual Overview. *Science Education 84(1)*, 71-94.

Lawson, A. E. (2010). *Teaching Inquiry Science in Middleand Secondary School (6th Edition).* Los Angeles: Sage.

Lincoln, Y. S., & Guba, E. (1985). *Naturalist Inquiry.* Newbury Park, CA: Sage Publications.

Llewellyn, D. (2011). *Differentiated Science Inquiry.* Thousand Oaks, CA: Corwin Press.

Maree, K. (2012). *First Steps in Research.* Pretoria: Van Shaik Publishers.

Maree, K., & Pietersen, J. (2011). Sampling. In K. Maree, *First steps in research* (pp. 172-181). Pretoria: Van Shaik.

Marx, R. W., Blumenfeld, P. C., Krajcik, J. S., Fishman, B., Soloway, E., Geier, R., & Tali Tal, R. (2004). Inquiry-based Science in Middle Grades: Assessment of Learning in Urban Systemic Reform. *Journal of Research in Science Teaching, 41*, 1063-1080.

Mattheis, F. E., & Nakayama, G. (1988). Effects of a Laboratory-Centered Inquiry Program on Laboratory Skills, Science Process Skills, and Understanding of Science Knowledge in Middle Grades Students. *(Eric Document Reproduction Service No. Ed 307 148)*.

Merriam, S. B. (2009). *Qualitative research: A Guide to Design and Implementation. 3rd Edition.* San Francisco: Jossey-Bass.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative Data Analysis (2nd edition).* Thousand Oaks, CA: Sage Publications.

Minner, D., Levy, A. J., & Century, J. (2010). Inquiry-Based Science Instruction-What is it and Does it Matter? Results from a Research Synthesis years 1984 to 2002. *Journal of Research in Science Teaching, 47*, 474-496.

Mullis, I. V., Martin, M. O., Ruddock, G. J., O'Sullivan, C. Y., & Preuschoff, C. (2011). Trends in International Mathematics and Science Study (TIMSS), Assessment Frameworks. *TIMSS and PIRLS International Study Centre.* Boston College: Lynch School of Education.

National Research Council [NRC]. (2000). *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning.* Washington, DC: National Academy.

Nieuwenhuis, J. (2011). Introducing qualitative research. In K. Maree, *First Steps in Research* (pp. 47-66). Pretoria: Van Shaik Publishers.

Novick, S., & Nussbaum, J. (1978). Junior High School Pupils' Understanding of Particulate Nature of Matter: An Interview Study. *Science Education, 62*, 273-281.

Novick, S., & Nussbaum, J. (1981). Pupils' Understanding of the Particulate Nature of Matter: A Cross-age Study. *Science Education 64(2)*, 187-196.

Novick, S., & Nussbaum, J. (1985). The Particulate Nature of Matter in the Gaseous Phase. In R. Guesne, & A. Tiberghien, *Children's Ideas in Science* (pp. 124-142). Buckingham: Open University Press.

Oche, E. S. (2012). Assessing the Relative Effectiveness of Three Teaching Methods in the Measurement of Student Achievent in Mathematics. *Journal of Emerging Trends in Educational Research and Policy Studies (JETERAPS)*, 479-486.

Oliver, R. (2007). Exploring an Inquiry-based Learning Approach with First-year Students in a Large Undergraduate Class. *Innovations in Education and Teaching International, 44*, 3-15.

Osborne, J., & Collins, S. (2001). Pupils' View of the Role and Value of the Science Curriculum: A Focus Group Study. *International Journal of Science Education, 23(5)*, 441-467.

Osborne, R. J., & Cosgrove, M. M. (1983). Children's Conceptions of the Changes of the State of Water. *Journal of Research in Science Teaching, 20*, 825-838.

Ozgelen, S., Yilmaz-Tuzun, O., & Hanuscin, D. L. (2012). Exploring the Development of Preservice Science Educators' Views on the Nature of Science in Inquiry-Based Laboratory Instruction. *Journal of Research in Science Education, 43,4*, 1551-1570.

Pascarella, E., & Terenzin, P. (2005). *How college affects students volume 2.* San Fransisco, CA: Jossey-Bass.

Patton, M. Q. (2002). *Qualitative Research and Evaluation Methods (3rd Edition).* Thousand Oaks: CA: Sage.

Pietersen, J., & Maree, K. (2011). Standardisation of a Questionnaire. In K. Maree, *First Steps in Research* (pp. 215-222). Pretoria: Van Shaik Publishers.

Poorman, P. B. (2002). Biography of role play. Fostering the empathy of abnormal psychology. *Teaching of Psychology*, 35-36.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accomodation of a Scientific Conception: Towards a Theory of Conceptual Change. *Science Education, 66(2)*, 211-217.

Pringle, M. (2006). Pre-service Educators' Exploration of Children's Alternative Conceptions: Cornestone for Planning to Teach Science. *Journal of Science Education, 17*, 291-307.

Ramette, R. W., & Haworth, D. K. (2006). What is your Mental Picture of Ordinary Air? *Journal of Science Education, 83(6)*, 834-837.

Ramnarain, U. (2010). A Report Card on Learner Autonomy in Science Investigations. *African Journal of Research in Mathematics Science and Technology Education, 14*, 61-72.

Saidi, S. M. (2004). *Teaching of Elementary Science.* Dehli: Anmol Publishers.

Schwandt, T. A. (2007). *The SAGE Dictionary of Qualitative Inquiry, Third Edition.* Retrieved from http://dx.doi.org/10.4135/9781412986281.

Scotland, J. (2012). Exploring the Phylosophical Underpinnings of Research: Relating Ontology and Epistemology to the Methodology and Methods of the Scientific, Interpretive, and Critical Research Paradigms. *English Language Teaching, 5*, 9-16.

Shenton, A. K. (2004). Strategies for Ensuring Trustworthiness in Qualitative Research Projects. *Education for Information, 22*, 63-75.

Singh, Y. K., & Nath, R. (2005). *Teaching of General Sciences.* New Delhi: Anmol Publishers.

Stojanovska, M. J., Soptrajanov, B. T., & Pertusevski, V. M. (2012). Adressing Misconceptions About the Particulate Nature of Matter Among Secondary School and High School Students in the Republic of Macedonia. *Scientific Research, 3(5)*, 619-631.

Szalavitz, M., Rahman, A., Fink, M., Wilson, S. Y., Chu, G., Aviles, M., . . . Matsuoka, B. M. (2004). Inquiry-based Learning. *Education Broadcasting Corporation (Workshop), available on http://www.thirteen.org/edonline/concept2class/inquiry/*.

Tlala, K. M. (2011). The Effect of Predict-Observe-Explain Strategy of Learner's Misconceptions about Dissolved Salts(Unpublished dissertation).

Veer, U. (2004). *Modern Teaching of Physics.* Dehli: Anmol Publishers.

Vygotsky, L. (1986). *Thought and Language.* Cambridge, MA: MIT Press (Original work published 1962).

APPENDICES

Appendix I: Pre-test adapted from Novick & Nussbaum (1985)

Test for grade 4 learners

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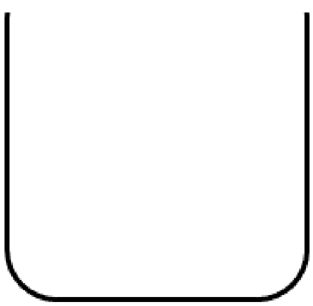
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

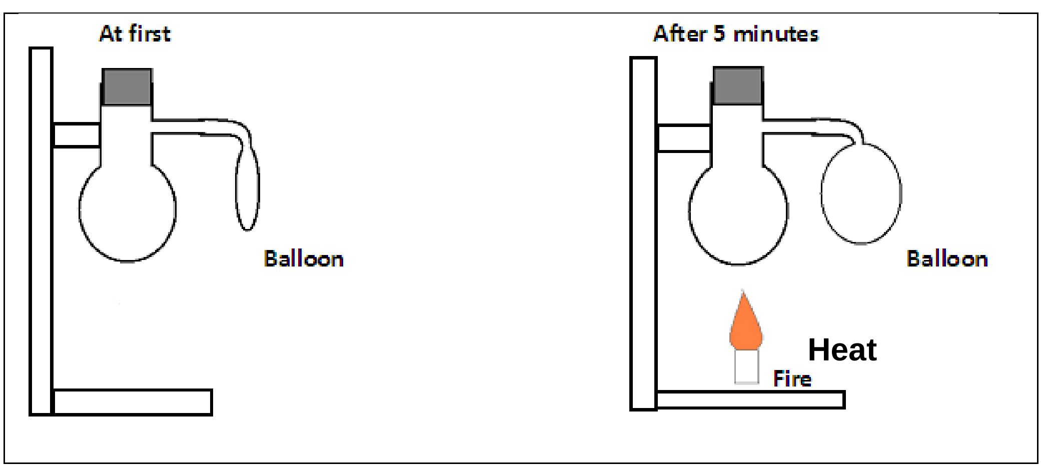
Question 1

The diagram below shows a glass beaker with air. Suppose you have magic glasses which can see the air inside the glass beaker. Use a pencil to draw the air in the beaker.



Question 2

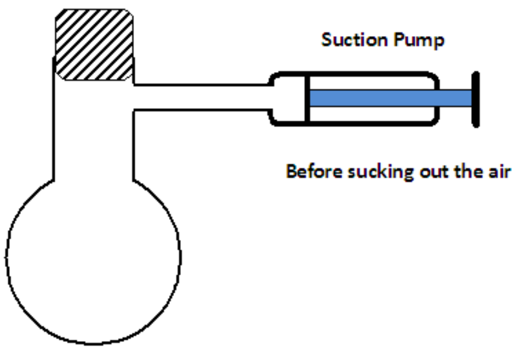
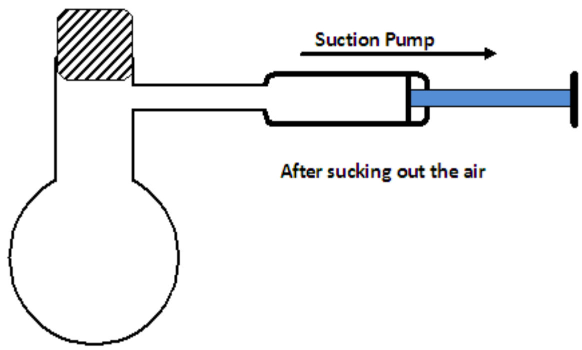
An **empty** glass bottle has a balloon tied at its end as shown below. The glass bottle is then heated without burning the balloon and the balloon became big. This is all shown in the diagram below.



If you have magic glasses which can see particles of the gas inside the bottle, show by use of a drawing the gas inside the bottle **before heating** and **after heating**.

Question 3

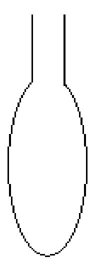
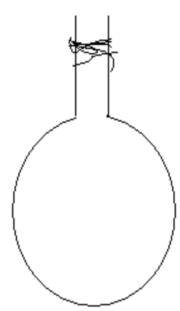
The diagram on the right shows a glass bottle connected to a suction pump.

Before suction of air	**After suction of air**
	

If air in the glass bottle could be seen by use of magic glasses, draw the air **before and after sucking** with the suction pump.

Question 4

A child in grade 1 blows air into a balloon. The diagram below shows the balloon before and after blowing in of air.

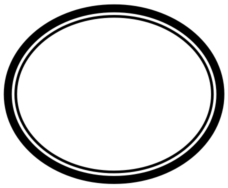
Balloon before blowing air	**Balloon after blowing air**
	

A grade 4 learner was asked to draw the air in the second balloon before and after blowing in air. **Draw the air in the ballons as you would see the air using magic glasses.**

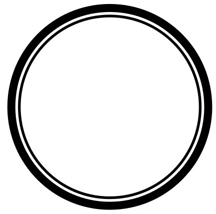
Question 5

Two identical soccer balls **one with a lot of air pumped in** and another **with less air pumped in** are shown below.

Less air in this



Much air in this



If you have magic glasses which can allow you to see air, draw the air that is inside each ball.

Appendix II: Interview schedule for focus-group interviews

UNIVERSITEIT VAN PRETORIA
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YUNIBESITHI YA PRETORIA

The learners participating in the interview were based on their drawing responses in the test. Learners were basically asked the same questions as below:

Explain why you have shown the drawings on this question like this?

What does it mean?

Why didn't you draw like this?

Appendix III: Interview schedule for grade 4 educators

The interview for grade 4 educators was based on their lessons observations during both the IBSE and the TCA.

7. After observing learners in the IBSE and the TCA lesson, which teaching approach do you think may result in increased understanding by learners and why do you think so?

8. Which teaching approach seemed interesting for the learners?

9. Which of these teaching approaches are you currently using?

10. Which of these teaching approaches would you recommend for use in teaching abstract and difficult topics? Explain your answer.

Appendix IV: Letter of informed consent for a minor child

Tshwane Christian School

P. Bag X03
Onderstepoorte

0110

Cell: 074 299 6108

Date: ………………………

Dear Parent(s)/Guardian(s):

RE: **REQUEST TO PARTICIPATE IN A RESEARCH PROJECT**

You may be aware that the performance of South African high school learners in science has been declining for almost a decade now. I am writing to ask your permission for your child to participate in a University of Pretoria research project, comparing inquiry based learning and lecture method on affecting learner understanding of the particulate nature of matter. In this project we will ask your child to make drawings to represent their understanding of arrangement of particles in the gaseous phase in the first day. For two lessons your child shall be taught by an expert using either the teacher-centred approach or the inquiry based method. Then on the last day your child shall make other drawing of the new understanding after lessons. Each time after drawings your child may be selected among the few who shall be interviewed so that they may explain the reasons of their choices.

This case study shall run for at most a week and your child shall be taught by another expert educator in the presence of the usual class educator and the researcher. The study is an attempt to make the study of science understandable and beneficial to learners, as well as to empower learners by involving them in decisions concerning their education. The use inquiry in science education may result in learners developing better understanding of science which may result in increased number of learners choosing science related careers in their future studies

We request your permission to allow your child to participate in this project, as we believe it will contribute to furthering our knowledge on the influence of inquiry-based science on the understanding of science. However, the decision about your child's participation in the project is entirely yours. You have the right to prevent your child from participating in the project without repercussion from the school or any other authority. Only learners whose parents/guardians will have willingly permitted their children to take part will be considered for the study. All information related to the study will be treated anonymously when reporting results. The identity of participating schools, educators and learners will be strictly confidential.

Should you have any concerns or comments related to your child's participation in this study, please contact Mr. C. Mamombe at cell phone number: 0742996108 or e-mail address: mamoocm@gmail.com . If you have any questions about the rights of your child as a participant, you may contact the University of Pretoria, Faculty of Education, Ethics Committee, at 012 420 3751.

If you are willing to allow your child to participate in the study, please kindly write your name and sign on the lines below, and return the letter to the school as soon as possible.

Informed consent form for participation in research

Please read the conditions below and sign if you agree that your child may participate.

With reference to the request for permission to conduct research entitled: ***The influence of Inquiry-Based Science Education on grade 4 learners' understanding of particulate nature of matter in the gaseous phase.***

I understand and agree that:

- My child shall be in one of the two grade 4 classes which shall be taught for two lessons by an experienced educator in the presence of the usual educators.
- Data shall be collect before, during and after the teaching and my child may participate in an interview.
- Data collected will only be used for research purposes.
- The identity of the school and my child will be held in the strictest confidence.
- The participation of my child and the school, in the project, is voluntary and the school can withdraw at any stage of the research.
- I am not waiving any human or legal rights by agreeing to participate in this study.
- I verify by signing below that I have read and understood the conditions listed above.

Parent/Guardian's name: .... signature.. Place and date: ....

Student's name: Mamombe Charles Signature: .... Student number: 12293581

Place and date: ....

Supervisor's name: Mrs. Mathabathe K. **Signature**: .... **Place and date**: .University of Pretoria, 08/03/ 2014.

If you have any questions about this research project, please contact Mrs. Mathabathe K. (Supervisor) by telephone on 012 420 2758 or email kgadi.mathabathe@up.ac.za.

Appendix V: Letter of informed assent for a minor child

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Tshwane Christian School

P. Bag X03
Onderstepoorte

0110

Cell: 074 299 6108

Date: ………………………

Dear Learner:

RE: <u>REQUEST TO PARTICIPATE IN A RESEARCH PROJECT.</u>

You may be aware that the performance of South African high school learners in science has been declining for almost a decade now. I am asking for your permission to participate in a University of Pretoria research project, on the influence of inquiry-based learning and the teacher-centred approach on learners' understanding of the particulate nature of matter in the gaseous phase. In this project you will be asked to make drawings to represent your understanding of air in the gaseous phase in the first day. After the test you may be asked to take part in a group interview with two other learners. In that interview you will be asked to explain your drawings.

Then you shall be taught by experienced educator for two lessons and write another test and have a second interview.

We ask you to participate in this study which may be helpful to you and the future grade 4 learners in their future studies. If you are willing to participate in the study read carefully the following paragraphs and sign.

Informed consent form for participation in research

Please read the conditions below and sign if you agree to participate in this study.

With reference to the request for permission to conduct research entitled: ***The influence of Inquiry-Based Science Education on grade 4 learners' understanding of particulate nature of matter in the gaseous phase.***

I understand and agree that:

- I shall be in one of the grade 4 classes which shall be taught for two lessons by an experienced educator in the presence of the usual educators.
- Data shall be collected before, during and after the teaching and I may participate in an interview.
- Data collected will only be used for research purposes.
- The identity of the school and my name will be held in the strictest confidence.
- The participation of the school and me, in the project, is voluntary and the school and or I can withdraw at any stage of the research.
- I am not waiving any human or legal rights by agreeing to participate in this study.
- I verify by signing below that I have read and understood the conditions listed above.

Learner's name: .... signature.. Place and date: ....

Student's name: Mamombe Charles Signature: .... Student number: 12293581

Place and date: ....

Supervisor's name: Mrs. Mathabathe K. **Signature**: .... **Place and date**: .University of Pretoria, 08/03/ 2014.

If you have any questions about this research project, please contact Mr. C. Mamombe at cell phone number: 0742996108 or e-mail address: mamoocm@gmail.com .

If not satisfied by response from the above please contact Mrs. Mathabathe K. (Supervisor) by telephone on 012 420 2758 or email kgadi.mathabathe@up.ac.za.

If you still have any questions, you may contact the University of Pretoria, Faculty of Education, Ethics Committee, at 012 420 3751.

Appendix VI: Letter of informed consent for principals

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Tshwane Christian School

P. Bag X03
Onderstepoorte

0110

Cell: 074 299 6108

Date ....

Dear PRINCIPAL:

RE: **REQUEST FOR PERMISSION TO CONDUCT A RESEARCH AT YOUR SCHOOL.**

I am a student in the Department of Science, Mathematics and Technology Education at the University of Pretoria, doing a research study entitled **"***The influence of Inquiry-Based Science Education on grade 4 learners' understanding of particulate nature of matter in the gaseous phase.*" I am requesting for permission to collect data at your school.

The aim of the study is to identify the influence of inquiry based science teaching and the teacher-centred approach on grade 4 learners' understanding of the particulate nature of matter in the gaseous phase. Two grade 4 classes at your school shall be given an initial test and shall be taught by two experienced educators in the presence of the usual class educator for two lessons. Each experienced educator shall teach one class using the inquiry based approach and the other experienced educator shall teach using the teacher-centred approach. After the two lessons the two classes shall write a second test similar to the first one.

All information related to the study will be treated anonymously when reporting results. The identity of participating schools, educators and learners will be strictly confidential. Your positive consideration of our request will be highly appreciated. Should you agree, please read and sign the attached consent form. Thank you very much for spending time to consider this request.

Kind regards.

Signed: .... Date...................

Mr. Mamombe C. Student number 12293581

Informed consent form for data collection

Please read the conditions below and sign if you agree that your school may participate.

With reference to the request for permission to conduct research entitled: **"***The influence of Inquiry-Based Science Education on grade 4 learners' understanding of particulate nature of matter in the gaseous phase.*" I understand and agree that:

- Two grade 4 classes at my school shall write a pre-test which last for about ten minutes.
- Two grade 4 classes at my school shall be taught for two lessons by an experienced educator in the presence of the usual educators.
- Data shall be collect before, during and after the teaching.
- Data collected will only be used for research purposes.

- The identity of the school, educators and learners will be held in the strictest confidence.
- This school's participation in the project is voluntary, and the school can withdraw at any stage of the research.
- I am not waiving any human or legal rights by agreeing to participate in this study.
- I verify by signing below that I have read and understood the conditions listed above.

School's name and stamp: ....

Principal's name: .... signature.. Place and date: ....

Student's name: Mamombe Charles Signature: .... Student number: 12293581

Place and date: ....

Supervisor's name: Mrs. Mathabathe K. **Signature**: .... **Place and date**: .University of Pretoria, 08/03/ 2014.

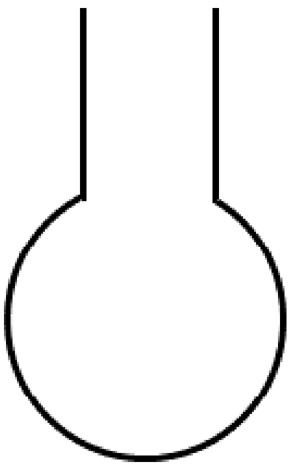
If you have any questions about this research project, please contact Mrs. Mathabathe K. (Supervisor) by telephone on 012 420 2758 or email kgadi.mathabathe@up.ac.za.

Appendix VII: Post-test (Adapted from Novick & Nussbaum, 1985)

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

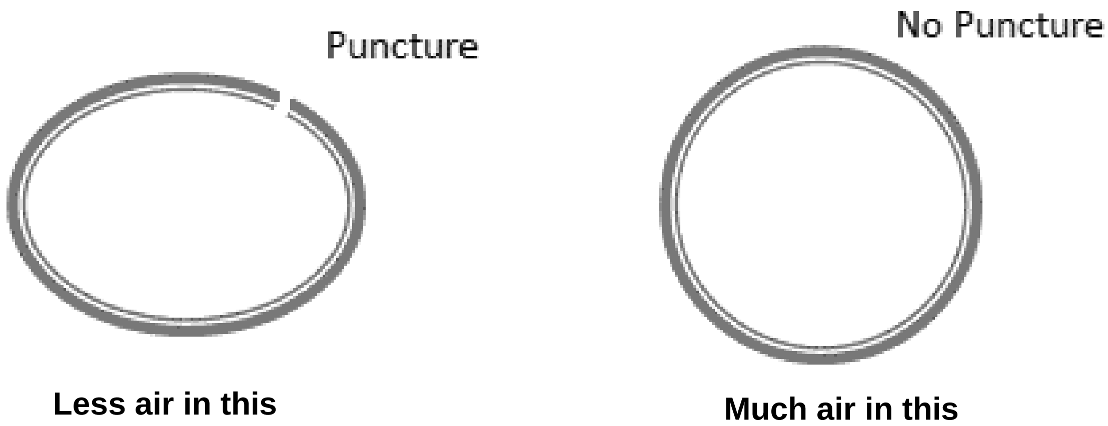
Question 1

The diagram below shows a glass bottle. Suppose you have magic glasses which can see the air inside the glass bottle Use a pencil to draw the air inside the bottle.



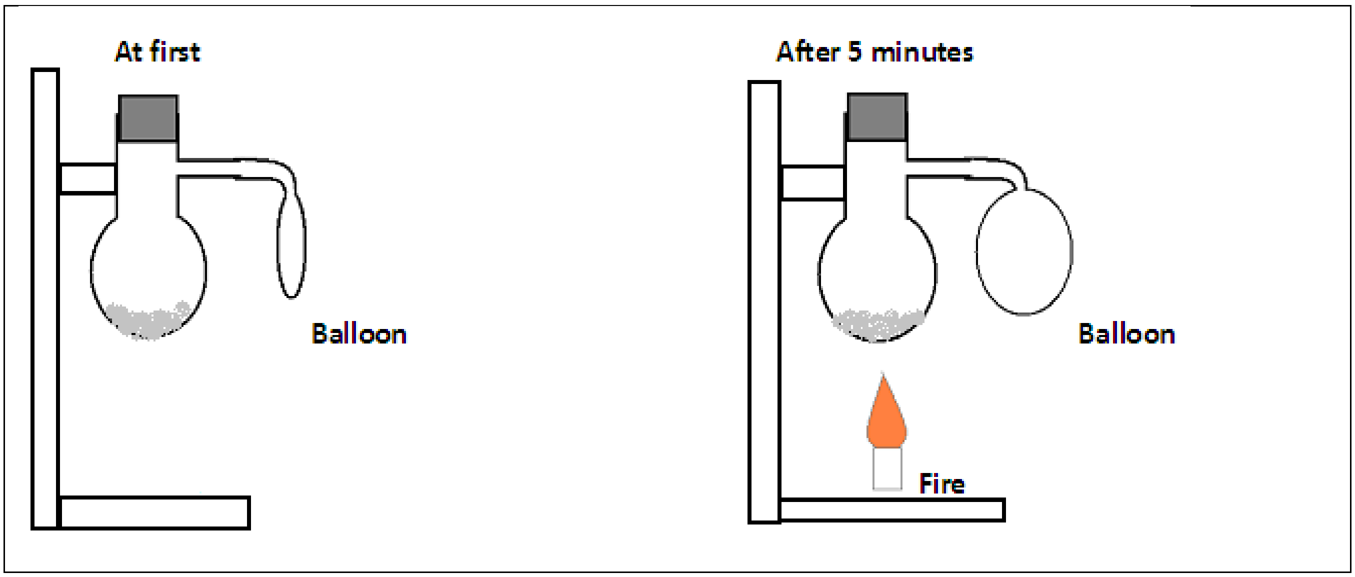
Question 2

Two identical soccer balls **one with a puncture a**nd another **without a puncture** were pumped with same amount of air. After some time the balls look like the diagrams below. If you have magic glasses which can allow you to see air, draw the air that is inside each ball.



Question 3

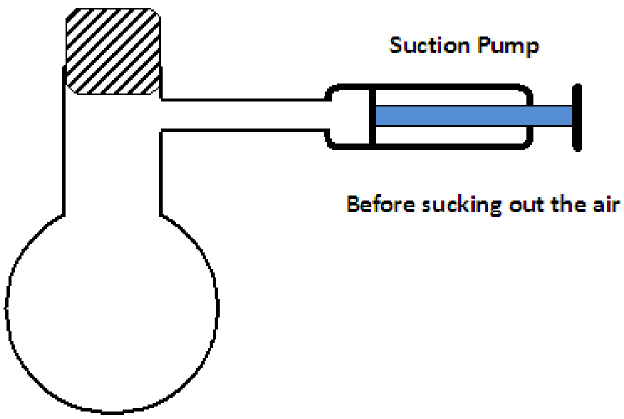
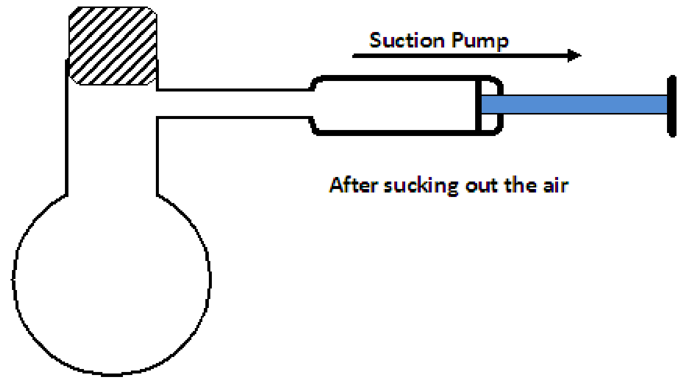
A glass bottle with water has a balloon tied at its end as shown below. The glass bottle is then heated without burning the balloon and the balloon became big. This is all shown in the diagram below.



If you have magic glasses which can see the air inside the bottle, show by use of a drawing, the air inside the bottle **before heating** and **after heating**.

Question 4

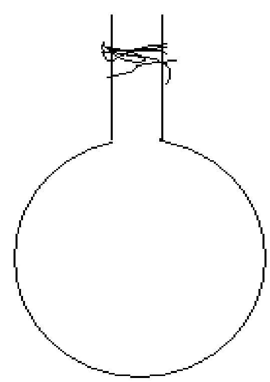
The diagram on the right shows a glass bottle connected to a suction pump.

Before suction of air	After suction of air
	

If air in the glass bottle could be seen by use of magic glasses, draw the air **before and after sucking** with the suction pump.

Question 5

A child in grade 1 blows air into a balloon. The diagram below shows the balloon before and after blowing in of air.

Balloon before blowing air	Balloon after blowing air
	

A grade 4 learner was asked to draw the air in the second balloon before and after blowing in air. **Draw the air in the ballons as you would see the air using magic glasses.**

Appendix VIII: Follow up Test for grade 4 learners: Gaseous Phase

UNIVERSITEIT VAN PRETORIA
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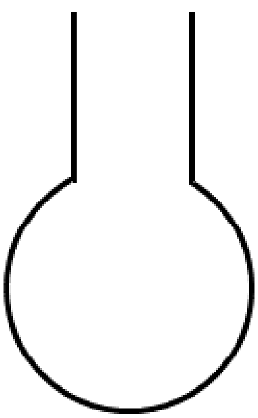
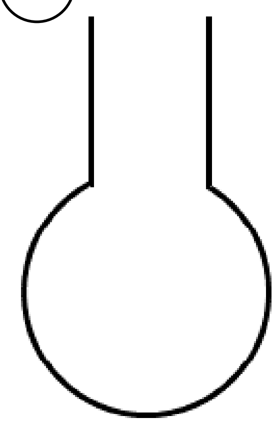
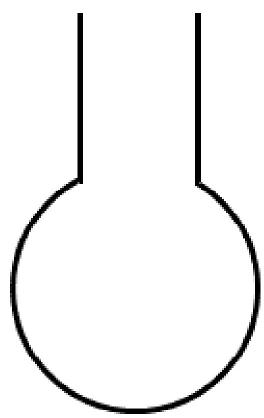
A few weeks ago you wrote a test during which you were drawing air in different containers. In this test, you will find answers given by some learners who wrote a similar test as you did.

You are required to choose which of the answers A, B, C, D, or E, is the most correct answer. Choose only a letter. Do not draw anything, just circle the correct answer.

All the drawings were drawn by the learners imagining that they were wearing magic glasses

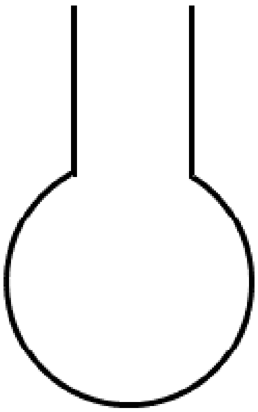
Each question has six (6) possible answers given by learners. Look at the answers carefully before choosing the most correct answer.

For example is the correct answer is B then circle B like this.

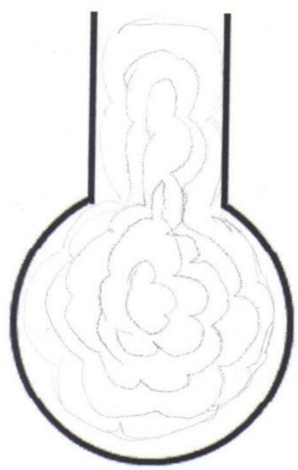
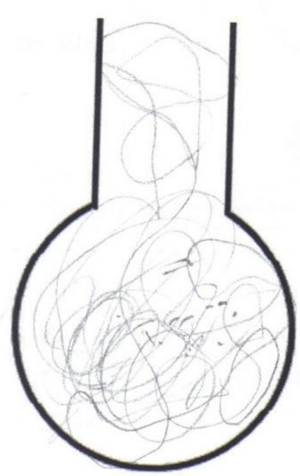
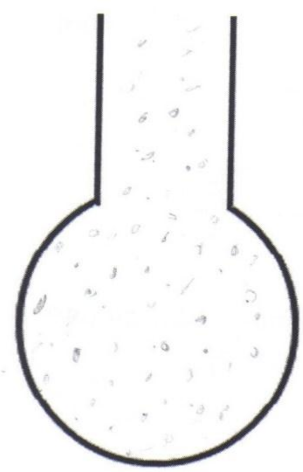
A	B	C
		

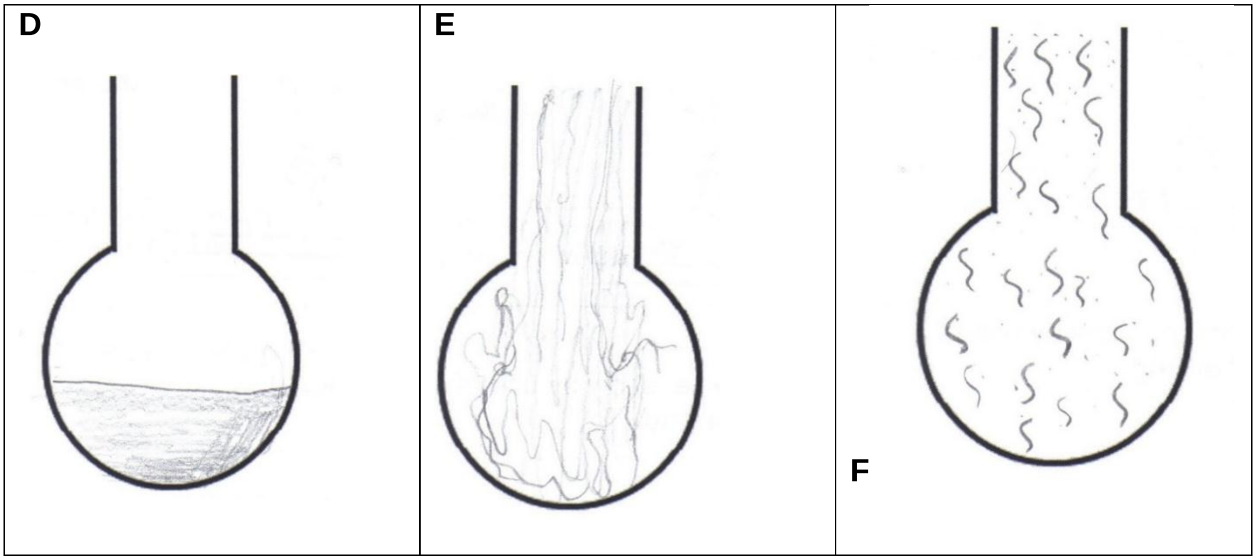
Question 1

The learners were asked to draw the air inside the glass bottle below.



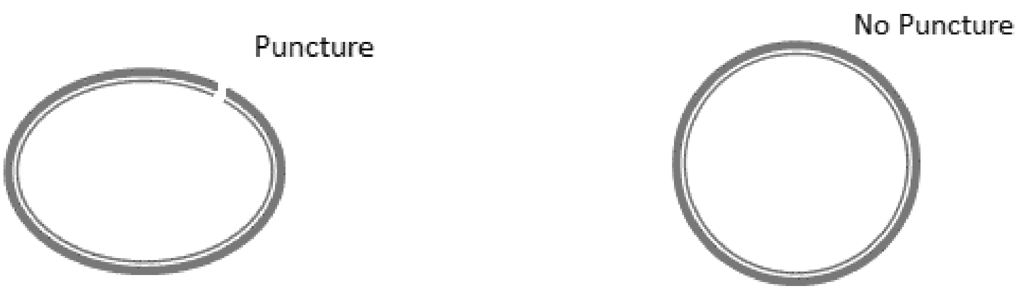
Choose the <u>most correct answer</u> to the question, from the answers given below.

A	B	C
		



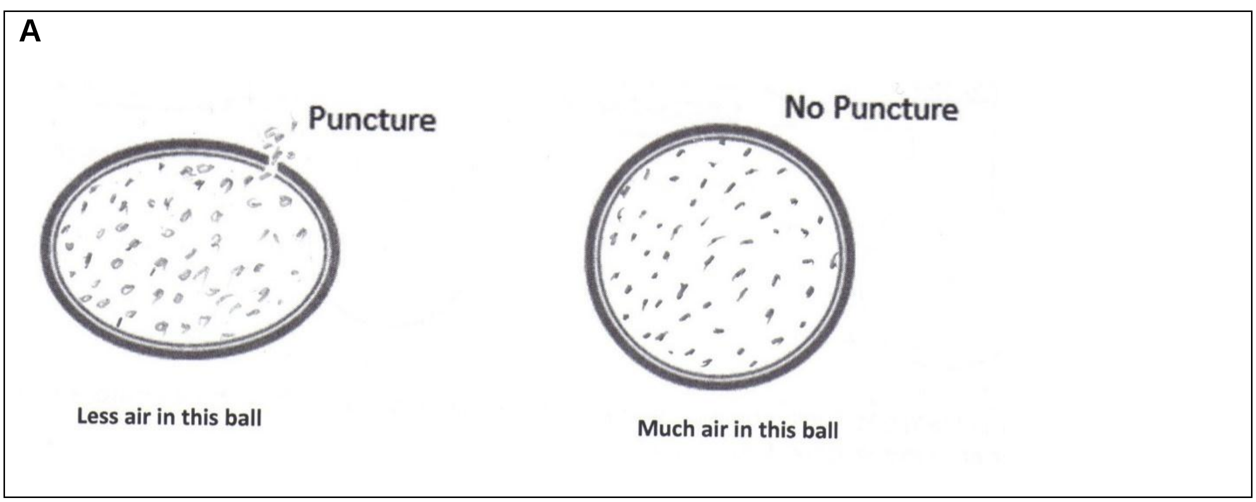
Question 2

Learners were given two identical soccer balls **one with a puncture a**nd another **without a puncture**.

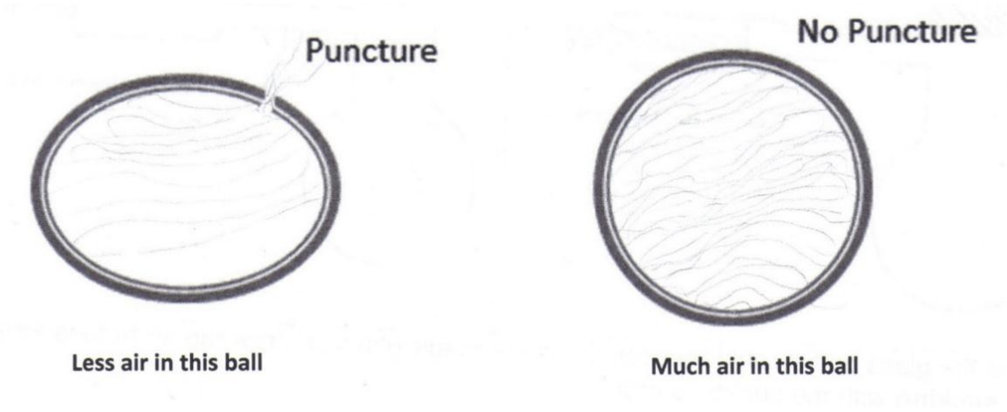


Less air in this **Much air in this**

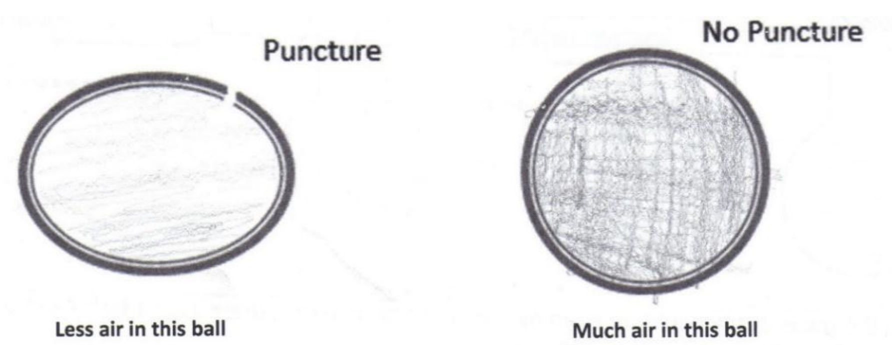
The responses of the learners were as follows. **Choose the best answer**



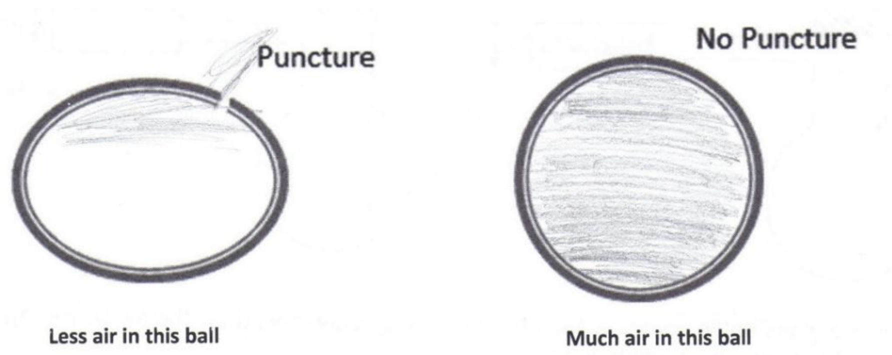
B


Puncture
No Puncture
Less air in this ball
Much air in this ball

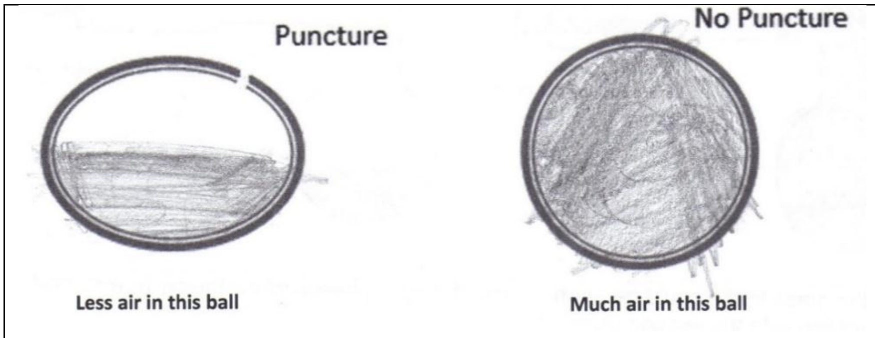
C


Puncture
No Puncture
Less air in this ball
Much air in this ball

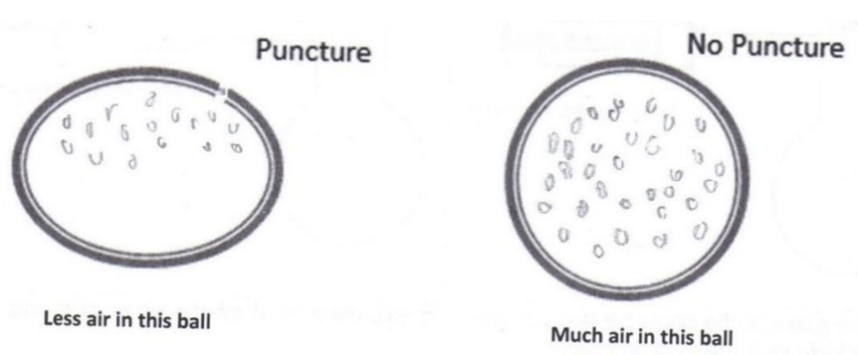
D


Puncture
No Puncture
Less air in this ball
Much air in this ball

E

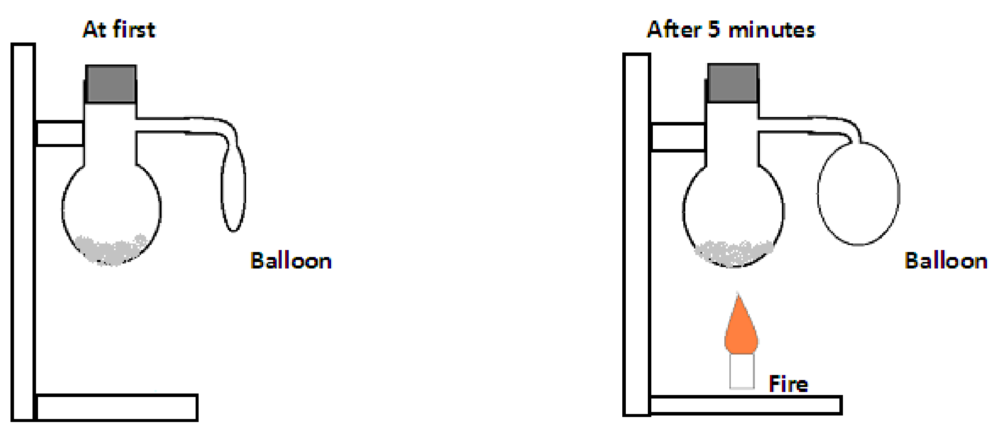


F



Question 3

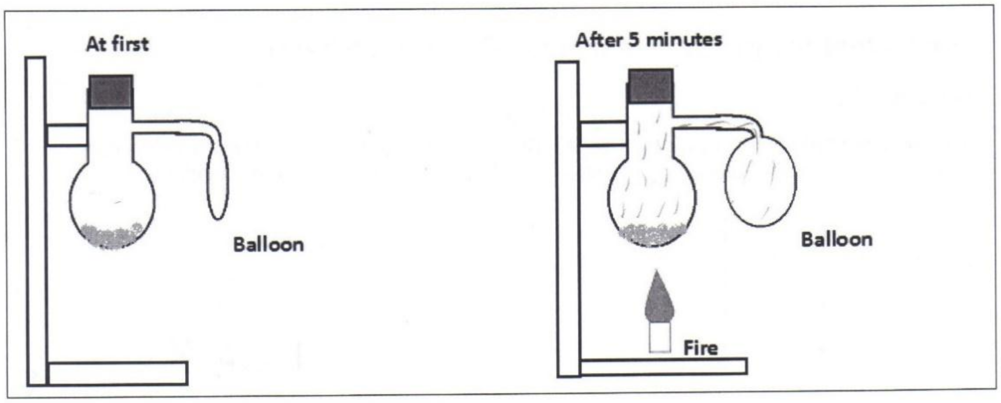
Learners were given drawings of a glass bottle with water and a balloon tied at its end as shown below. The glass bottle is then heated without burning the balloon and the balloon became big.



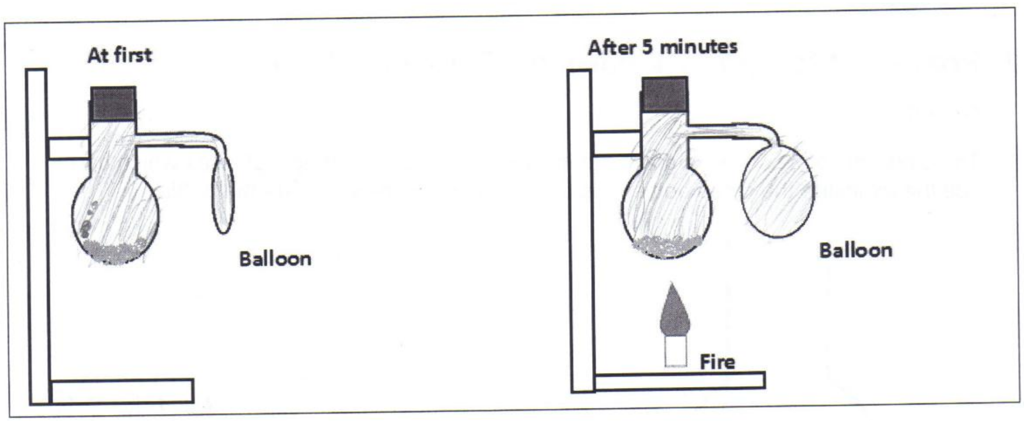
The answers of the grade 4 learners were as follows.

<u>Which answer is the most correct drawing of air?</u>

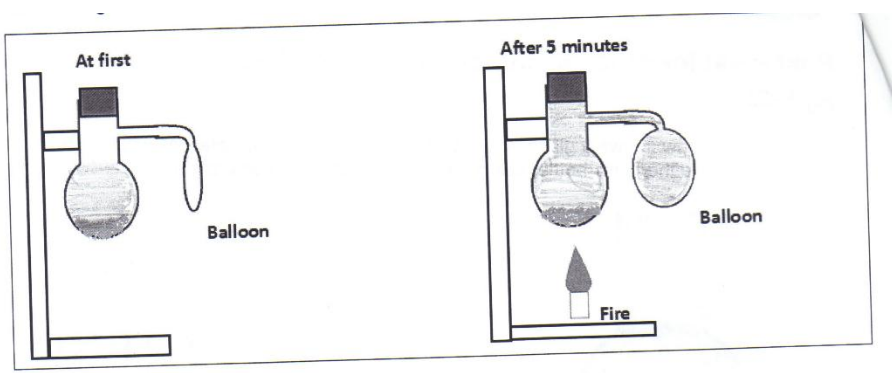
A


At first
Balloon
After 5 minutes
Balloon
Fire

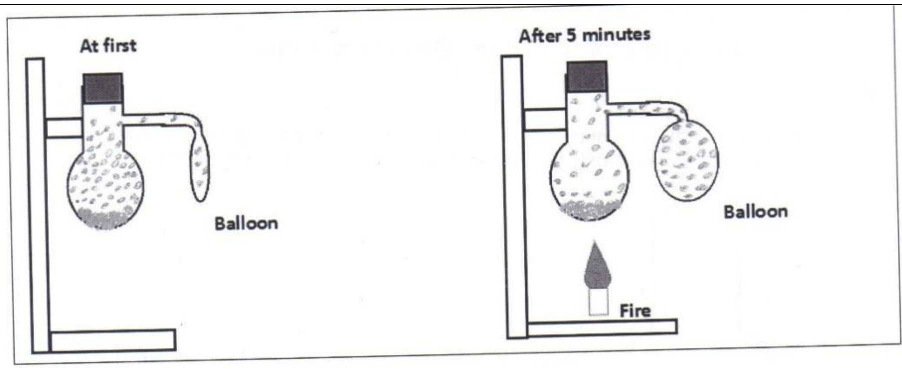
B


At first
Balloon
After 5 minutes
Balloon
Fire

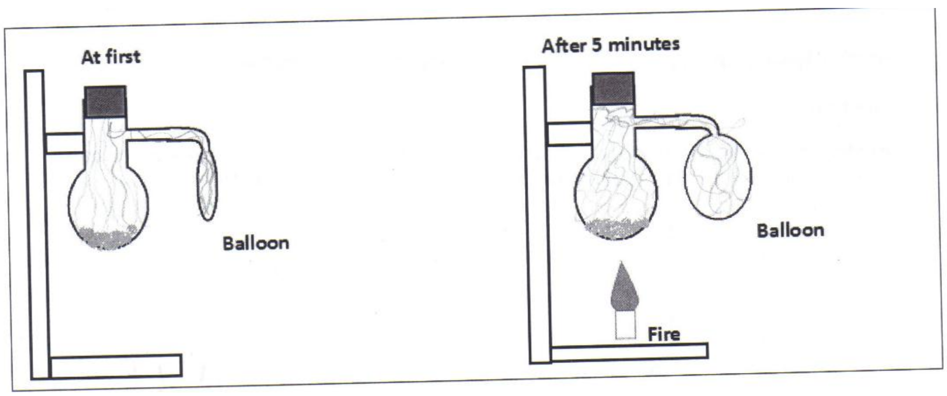
C


At first
Balloon
After 5 minutes
Balloon
Fire

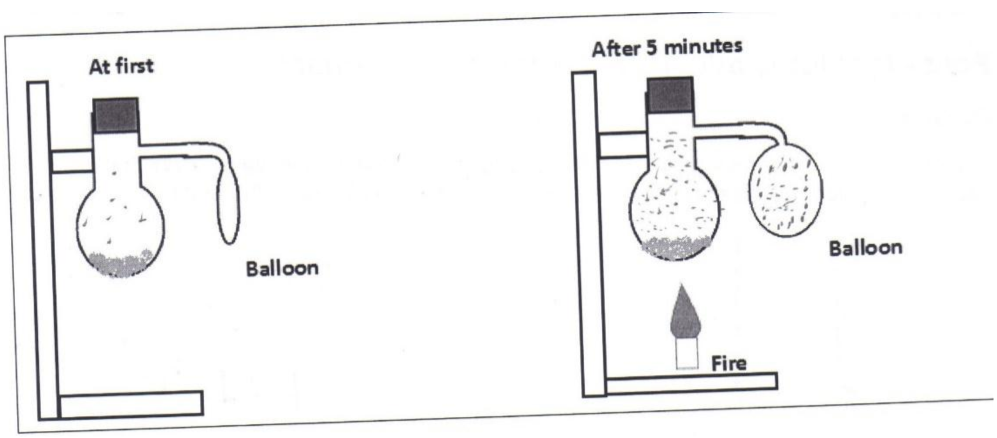
D



E

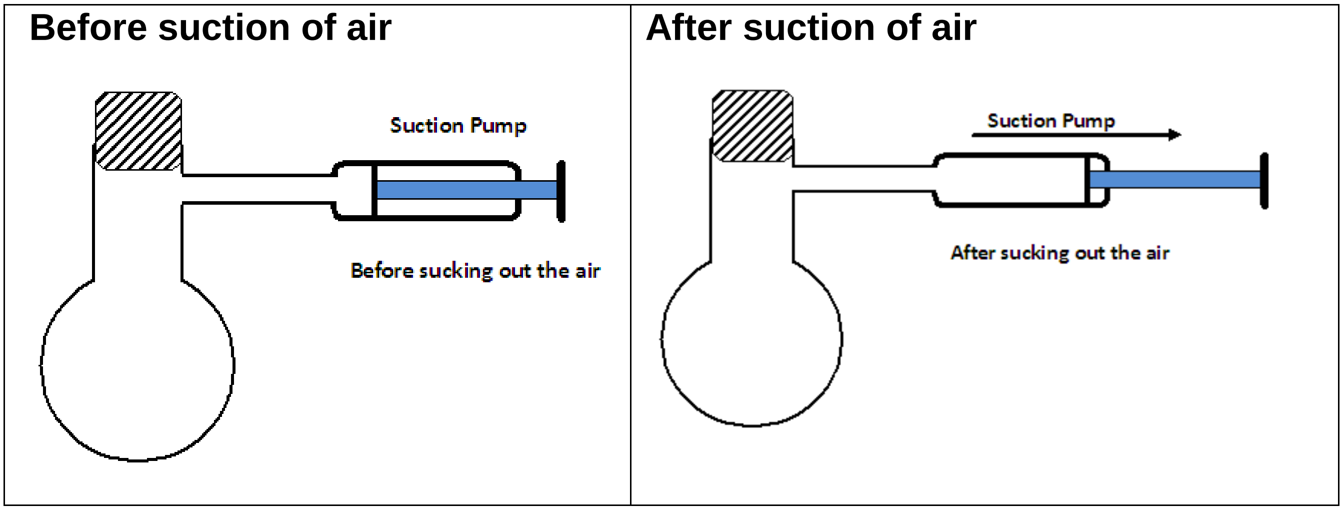


F



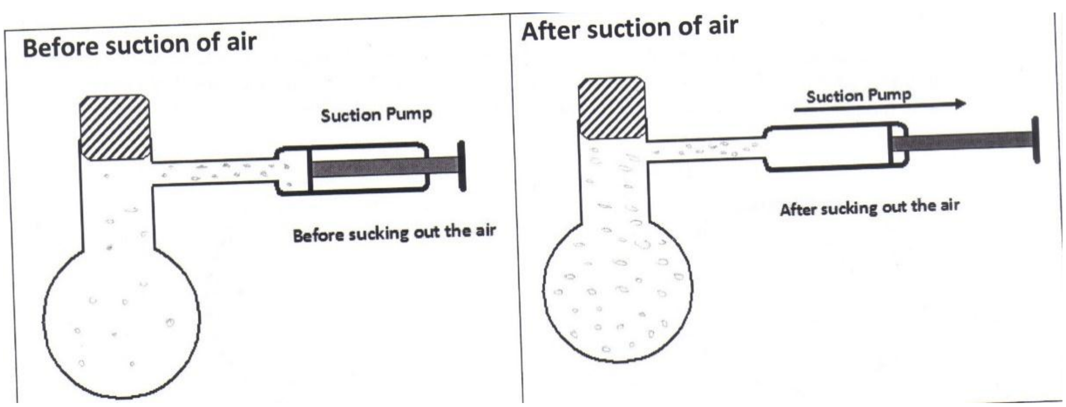
Question 4

Learners were given drawings of a glass bottle connected to a suction pump, before and after suction.

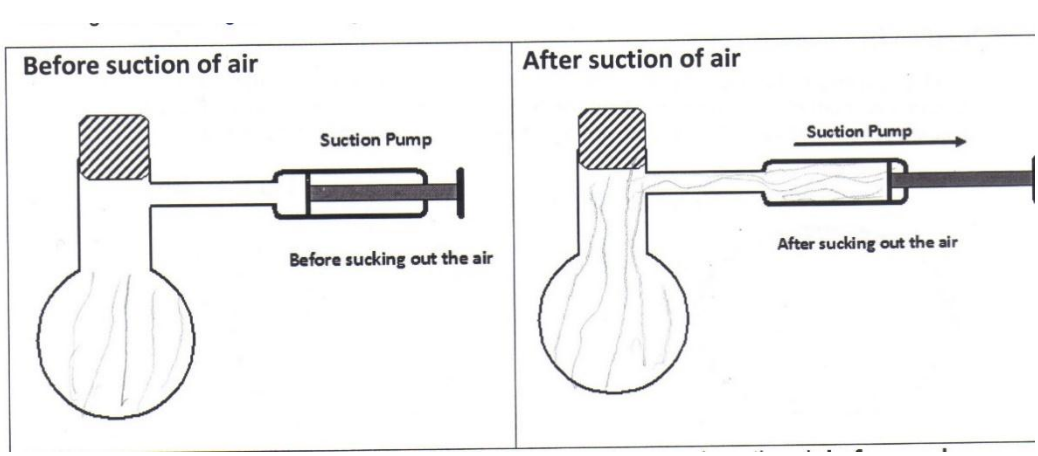


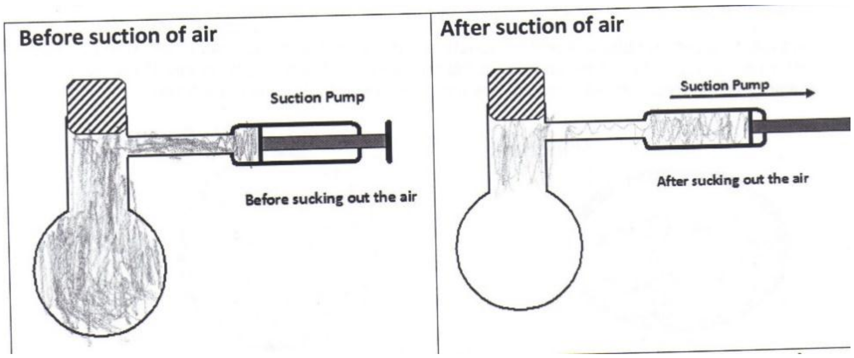
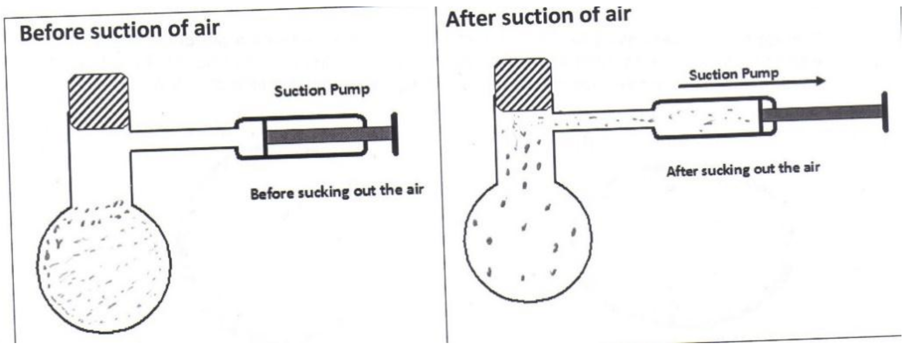
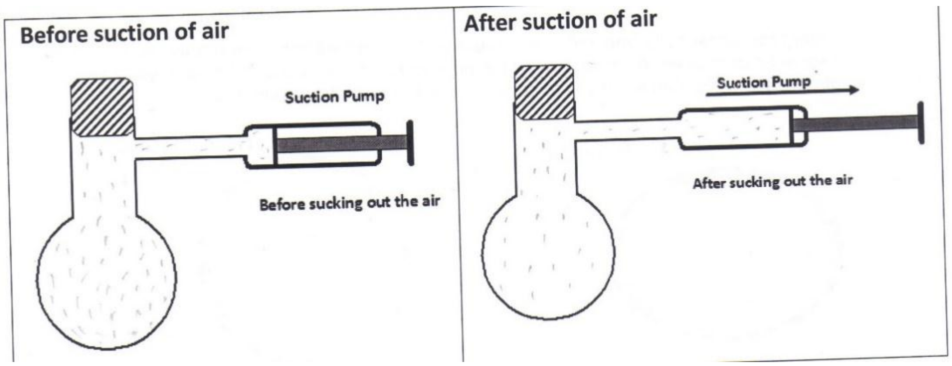
The answers of some of the grade 4 learners were as follows. Which answer is the most correct drawing of air?

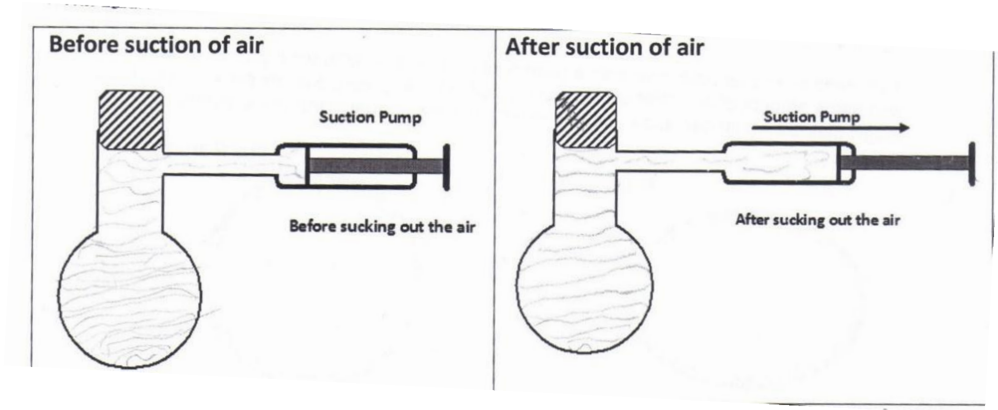
A



B

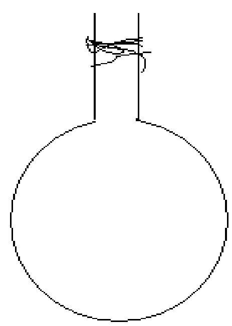


C  Before suction of air Suction Pump Before sucking out the air After suction of air Suction Pump After sucking out the air
D  Before suction of air Suction Pump Before sucking out the air After suction of air Suction Pump After sucking out the air
E  Before suction of air Suction Pump Before sucking out the air After suction of air Suction Pump After sucking out the air
F



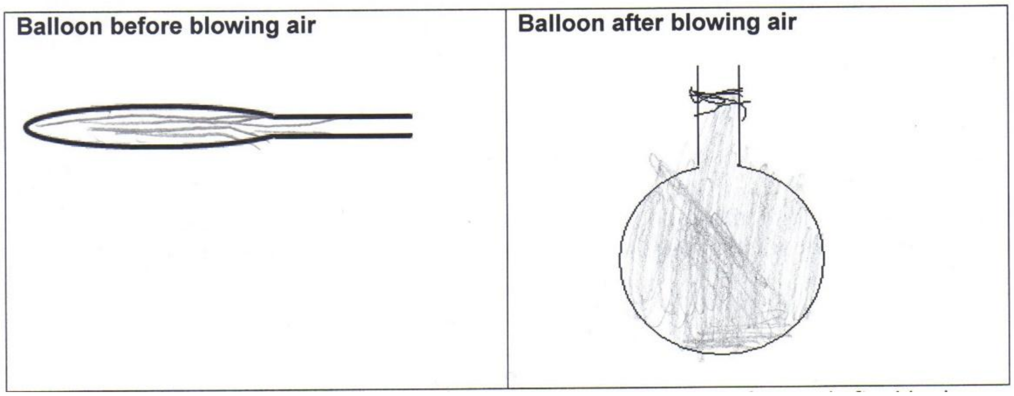
Question 5

The grade 4 learners were given a drawing of a balloon before blowing in air and another after blowing air. The diagram below shows the balloon before and after blowing in of air.

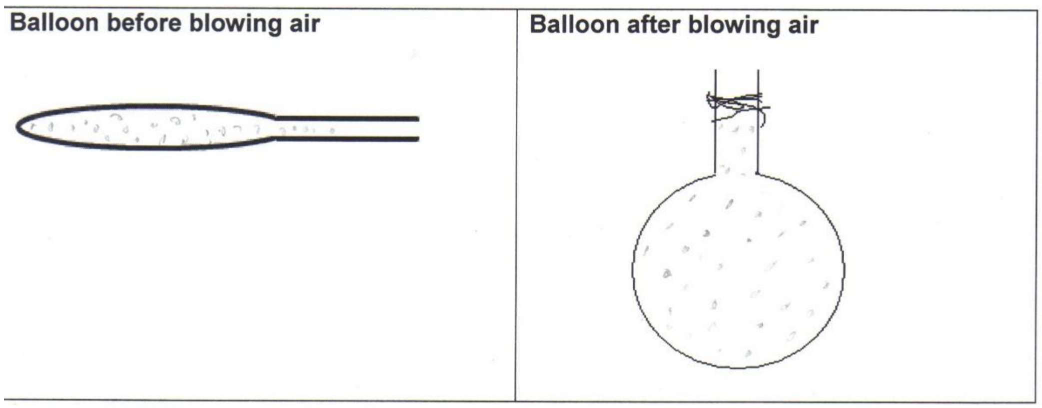
Balloon before blowing air	**Balloon after blowing air**
	

The answers given by some grade 4 learners were as follows. <u>Choose the most correct answer to the drawing.</u>

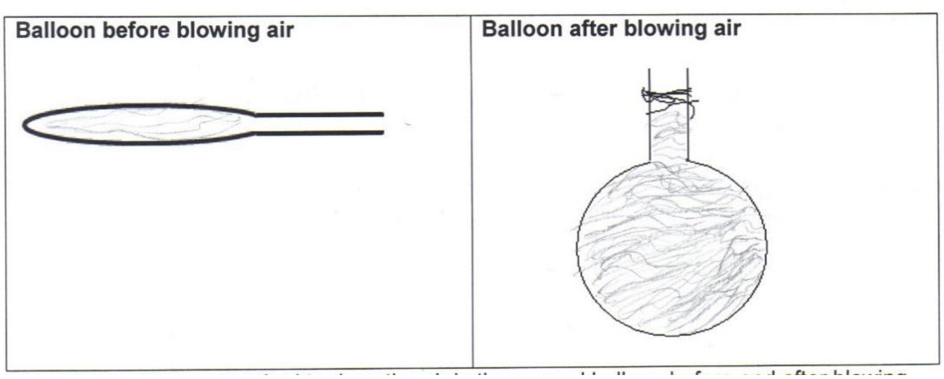
A	


Balloon before blowing air
Balloon after blowing air

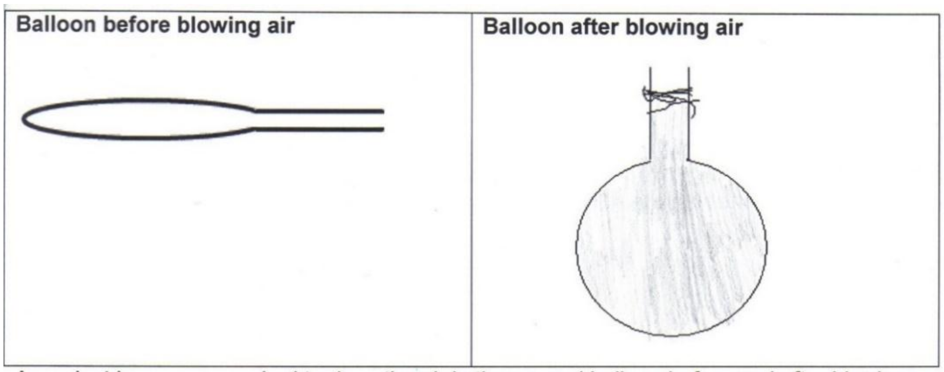
B


Balloon before blowing air
Balloon after blowing air

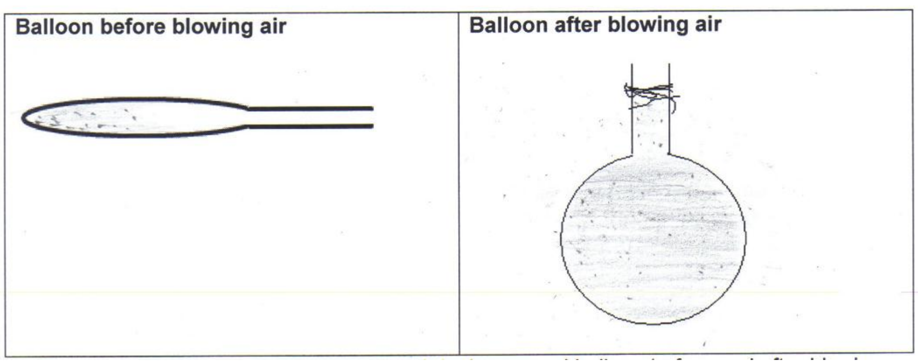
C


Balloon before blowing air
Balloon after blowing air

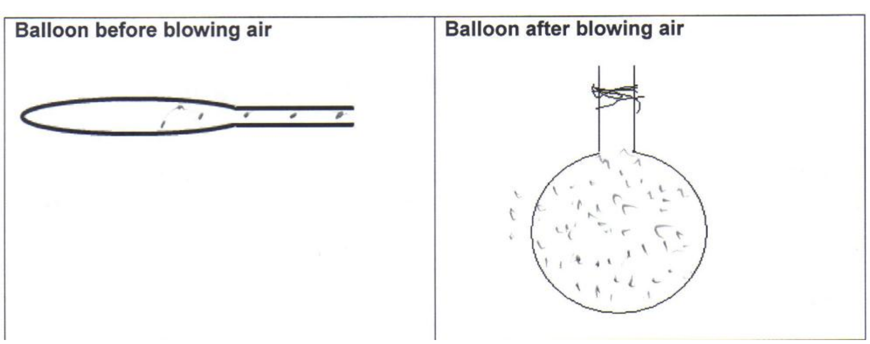
D


Balloon before blowing air
Balloon after blowing air

E


Balloon before blowing air
Balloon after blowing air

F


Balloon before blowing air
Balloon after blowing air

Appendix IX: Lesson plans for IBSE method

Adapted from Bybee (2011).

Lesson 1: Air is made up of particles which can move.

Duration: 1 hour

Lesson stage	**Educator's activities**	**Learner activities**
Task 1: Air as seen using magic glasses.		**Duration: 60 minutes**
Engage	Teacher introduces the term 'particles' by asking learners of their awareness of the concept. Asks questions like; • How would you draw air if you can see it using magic glasses? • How does air move from one place to another?	Based on the pre-test experience learners are expected to be interested in the lesson. Learners ask themselves questions about their ideas of air structure.
Explore	Teacher gives each group of learners a can of air fresher. Teacher asks learners to use the air freshener to find out how air moves from one part of the room to their noses. Provides time for learners to work. Educators observes and listens, asks probing questions like; • After spraying the can does the air smell differently? • What causes the new smell? • How did the smell come to your nose from where it was sprayed? Teacher asks learners to make their drawings of air.	Learner tries many different drawings of air according to their hypotheses. Learners may ask teacher for guidance. Learners record new observations.
Explain	Asks learners to make their drawings. Teacher asks learners to give justification of their drawings. Teacher may make drawings of particles as previously drawn by learners in the pre-test and ask questions like; • How do the bits of soil look like?	Learners make use of probing questions to make suitable drawings. Explain to others. Listens critically to educator and peers. Uses recorded observations to explain giving justification

	• How will the air particles look like? Educator asks for clarification and evidence using learners' previous experiences. Encourages learners to explain their observations in their own words.	
Elaborate	Teacher encourages learners to use alternative ideas and their observations to make their drawings. Teacher encourages learners to give appropriate justifications for their drawings. Teachers asks probing questions like; • How does air perfume come from the other end to your nose? • How can you show that movement in a drawing? Teacher reminds learners of alternative ways like the drawings on annexure XIV and ask learners to make their own drawings.	Learners use previous knowledge and probing questions from teacher, and their observations. Learners draw air as they have agreed in their group giving justification of their drawings. Learners use previous knowledge and their observation to make reasonable conclusions on the appearance of their drawings.
Evaluate	Teacher observes learners as they apply new concepts. Teacher assesses learners' knowledge and skills. Teacher looks for evidence of conceptual change. Teacher allows learners to assess knowledge giving justification of their drawings.	Learners apply new knowledge in drawing perfume and air particles. Learners justify their drawings. Learners demonstrate understanding by justifying their drawings. Learners evaluate own progress.
Task 2: What is the shape of air?		**Duration: 60 minutes**
Engage	Teacher provides a beaker and different shaped balloon to each group of learners. Teacher ask learners: • Does air have a shape? • What shape does air have?	Based on the pre-test and task 1 learners are expected to be interested in the lesson. Learners ask themselves questions about their ideas of air structure. Learners' attention may be drawn quickly to the availability of balloons

	• How does the shape of air look like? Teacher asks learners to use the given apparatus and any other to answer the question on the shape of air.	on their desk. Learners may start to think wide on the background of shapes they know.
Explore	Teacher encourages learners to make their own drawings of balloons after blowing and beaker, and also to draw the air inside them. Teacher reminds learners that air is made up of particles. Teacher encourages learners to show particles in their drawings. Teacher asks learners; • What shape is each balloon? • What shape is the air in each balloon? • What shape is the air in the beaker? • Does air have a fixed shape? If so, what shape? If not, what shape does air have?	Learners may start to blow the balloons and identify the shapes of the balloons. Learners draw the balloons and the air in the balloons. Learners also state the shape of the beaker and draw also the air in the beaker. Learners try to state the different shapes of balloons. Learners make use of probing questions to find the shape of air.
Explain	Teacher provide correct names of shapes like cylindrical, spherical, oval, multiple oval, square prism, rectangle prism, cone Teacher does not tell the shape of air. Teacher encourages learners to describe the shape of air based on the shape of container. Teacher may make drawings of balloons and label the names of their shapes.	Learners should identify the names of the shapes for the beaker and different balloons. Learners should draw and describe the shape of air in the balloons and beaker. Learners should also give justification of the names of the shapes of air in each container.
Elaborate	Teacher encourages learners to refer to the chalkboard for the correct names of shapes, or for them to use alternative names. Teacher encourages learners to make	The learners apply knowledge from previous task to draw air in the beaker and balloons. Learners apply previous and names of shapes provided to state the

	drawings of air in the balloons and beaker Teacher reminds learners that air exists in the form of particles.	shape of air in each container. Learners make drawings of air in different containers. Learners make conclusions on the
Evaluate	Teacher assesses learners' knowledge and skills. Teacher looks for evidence of conceptual change. Teacher asks open-ended questions like; • Why do you say air in the beaker has that shape? • How does the air in the balloon look like? • Is air in the balloon filling up the whole balloon or is the air at the centre or is it on the sides? • Justify your responses.	Learners answer open-ended questions using previous knowledge. Learner demonstrate understanding of concepts by justifying their choice of shape of air. Learners evaluate themselves based on available knowledge. Learners may ask for clarification of air in the balloon where at the centre, sides or whole container.

Lesson 2: Compression and expansion of air

Duration: 1 hour

Task 1: Compressing air in the syringe and pumping air out of syringe		**Duration: 60 minutes**
Engage	Teacher asks learners of their experience with a bicycle pump. Teacher introduces syringe in place of bicycle pump. Teacher demonstrate by pumping the syringe in and by pumping the syringe out with the mouth end of syringe closed.	Learners show interest in the syringe since it looks like a bicycle pump and something to play with. Learners want to get a chance to touch the syringe and manipulate it. Learners refer to their

	Teacher asks; • Before pushing the syringe how does air inside the syringe look like? • After pushing the pump with syringe mouth end closed how does air inside it look like? • When pulling out the syringe how does air look like?	knowledge of bicycle pump. Learners start to think of hypotheses of what happens in the pump. Learners start to think of possible particulate arrangement of air particles inside the syringe.
Explore	Teacher gives a syringe per group and encourages learners to start pushing the syringe in with mouth closed and them pulling out the pump with the mouth closed. Teacher observes and listens to learners' discussions. Teacher asks probing questions like; • When you pump in what do you feel on the finger closing the mouth of the pump? • Do you think you can pump it until it reaches the end? If not, why not? • When you release the pump after pushing but still holding the mouth end, why does the pump go backwards?	Learners manipulate the syringe giving turns to member of the group. Learners use knowledge from previous tasks to decide on the drawings of air in the syringe before pumping. Learners think of reasons for their drawings. Learners push the pump of syringe and observe what happens and writing down their observations. Learners pull the pump and observe what happens and record their observations.
Explain	Teacher encourages learners to explain in their own words. Teacher encourages learners to justify their idea using particulate arrangement. Teacher explains that when you push in the pump the air is 'compressed', and when the pump is pulled the 'expands'	Learners explain why they made their justification. Learners explain to each other how the particles in the syringe before pushing, after pushing and after pulling the pump. Learners try to hypothesize different ideas for why the pump pushes backwards after compression.

Elaborate	Teacher expects learners to use their knowledge and particulate understanding of matter in the gaseous phase draw air in the pump before pumping and after pumping and before suction and after suction. Teacher encourages learners to refer to previous understanding of particulate arrangement asking questions like; • How do we draw particles? • How are particles arranged before pushing in the pump? • How are particles arranged after pushing in the pump? • How are the particles arranged after pulling out the pump?	Learners make use of probing questions to make their drawings giving justification. Learners use previous knowledge of air drawings to make drawings in pump in the different situations. Learners use previous knowledge and understanding to draw up conclusions. Learners record observation and explanations.
Evaluate	Teacher observes learners as they apply new concepts. Teacher assesses learners' knowledge and skills in drawing air in different situations. Teacher looks for evidence of conceptual change on learners' drawings and explanations.	Learners answer open-ended questions to make drawings on similar situations. Learners demonstrate understanding of particulate model by using dots or circles to show air particles.
Task 2: Expansion of gases by demonstration		**Duration: 60 minutes**
Engage	Teacher presents the apparatus of a round bottomed flask with lateral tube on a stand with a balloon tied to the end of the lateral tube and a stopper fitted at its mouth. The flask has some little water. Teacher places a burner at the bottom of flask without lighting it. Teacher asks learners what they see at the teacher's desk.	Learners start to examine the apparatus. Learners theorize on particulate arrangement in the flask and balloon. Learners hypothesize on what happens when burner is lit. Learners make use of probing questions to start

	Teacher asks for the functions of the apparatus especially the burner. Teacher asks; • How does air look like in the flask? • Is there air in the balloon? If yes, how does it look like? • If we light the burner what do you think will happen to the air in the flask? What will happen to the air in the balloon? How will the air in the balloon and flask look like? • What will happen to the balloon?	preparing responses to the task.
Explore	Teacher asks learners to go in groups and discuss and make drawings of air in flask and balloon before and after heating. Teacher listens to learners as they make their discussions and drawings. Teacher asks probing questions as learners work in their groups making drawings of air in the apparatus before and after heating. Teacher lights the burner and allows learners to observe what happens.	Learners work in groups coming up with their own drawings of air in the flask and balloon before and after heating. Learners make use of teacher's probing questions to answer the question. Learners look for reasons to justify their explanations and drawings.
Explain	Teacher encourages learners to describe their drawings before and after heating. Teacher encourages learners to make appropriate drawings of air in the apparatus and give possible reasons for the enlarging of the balloon. Teacher reminds learners of the concepts 'expansion'.	Learners are expected to use previous knowledge of expansion in previous tasks to describe what happens to the balloon. Learners provide possible solution and drawings of air. Learners refer to previous lessons and make reasonable justification.
Elaborate	Teacher expects learners to use previous knowledge to justify enlargement of the balloon.	Learners make appropriate responses based on previous knowledge.

	Teacher encourages learners to explain their findings and write their observations. Teacher reminds learners of their previous knowledge of particulate arrangement. Teacher asks; • What do you remember about the arrangement of air particles? • How do the particles look like before and after expansion of balloon? • What does heat cause particles to do?	Learners use previous information to make decision and make justification of their responses. Learners make use of probing questions to answer the question. Learners record observations and explanations.
Evaluate	Teacher observes learners as they apply new concepts and skills. Teacher looks for evidence of conceptual change. Teacher asks open-ended questions like; • What evidence do you have? • What do you know happens when air expands? • How will the air in the flask and balloon look like after heating? • What reasons do you have for your drawings?	Learners answer open-ended questions using previous knowledge. Learners demonstrates an understanding or knowledge of particulate arrangement by their drawings. Learners assess their own understanding.

Appendix X: Lesson plans for lecture method (**Adapted from Bybee (2011)**)

Lesson 1: Air is made up of particles which can move.

Duration: 1 hour

Task 1: How air looks like. **Duration: 30 minutes**

Lesson stage	**Educator's activities**	**Learner activities**
Engage	Teacher introduces the term 'particles' by telling learners how to draw. Teacher tells how air move from one place to another?	Learners ask for the right answers on how to draw air and how air looks like.
Explore	Teacher tells learners that if you spray air freshener the air freshener will spread and fill the whole room. Teacher tells learners of different kinds of fragrance that can be found in the shops. Teacher draws the air for the learners.	Learners listen to the teacher and write down notes in their books. Learners write down the names of fragrances provided by the teacher. Learners copy the drawings made by teacher.
Explain	Teacher does not ask for learner explanation. Teacher may attend to few questions from learners. Teacher may repeat what he said in the notes	Learners accept what the teacher says without much questioning or reasoning. Learners sit and listen.
Elaborate	Teacher explains step by step how to the draw air in different containers. Teacher provides no justification of the drawings. Teacher lectures about air movement from one place to another.	Learners listen as teacher is lecturing. Some learners pay no attention to what the teacher is saying because they already have the notes. Some learners may not pay attention or may be doing other activities instead of listening to the teacher
Evaluate	Tests vocabulary words like diffusion and isolated facts. Introduces new ideas and facts. Promotes open-ended discussion unrelated to the concept.	Learner response using 'yes' or 'no' without justification. Offers memorized answers and may read the notes. Cannot give justification of his answer.

Lesson 1: Air is made up of particles which can move.

Task 2: What is the shape of air?		**Duration: 30 minutes**
Engage	Teacher draws shapes of beaker and balloons Teacher instructs learners to copy the drawings. Teacher tells the learners the different shapes on the drawings.	Learner copy the shapes drawn by the teacher. Learners copy the shapes and write their names
Explore	Teacher draws the air inside the beaker and the balloons. And ask learners to copy. Teacher tells the learners the shape of the air inside the beaker and different shaped balloons. Teacher writes notes on the board for the learners to copy.	Learners copy the drawings of air into their books Learners write down the names of the shapes of air. Learners take down notes in their books.
Explain	Teacher provide correct names of shapes. Teacher explains that air fills the whole container. Teacher gives learners the notes	Learners accept what the teacher says without much questioning or reasoning. Learners sit and listen.
Elaborate	Teacher shows the names of different shapes to the learners Teacher encourages learners to copy drawings of air in the balloons and beaker Teacher reminds learners that air exists in the form of particles.	Learners copy correct names of the shapes. Learners listens to teacher but some learners may be not paying attention Learners take down the notes
Evaluate	Tests vocabulary words which learners my not be aware of. Introduces new ideas and facts. Promotes open-ended discussion unrelated to the concept.	Learner response using ‘yes’ or ‘no’ without justification. Offers memorized answers and may read the notes. Cannot give justification of his answer.

Lesson 2: Compression and expansion of air

Duration: 1 hour

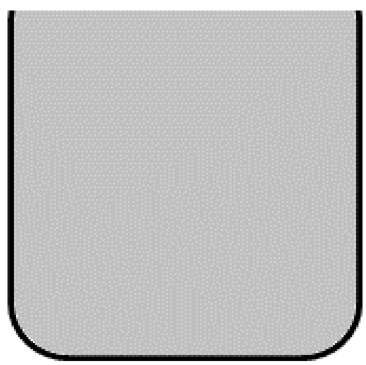
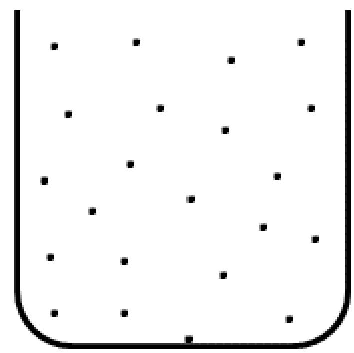
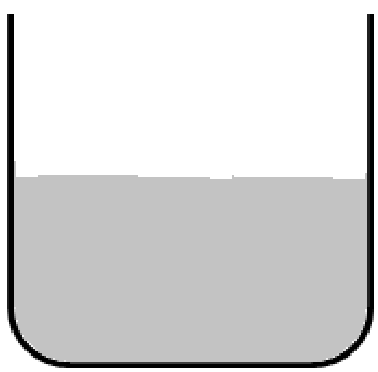
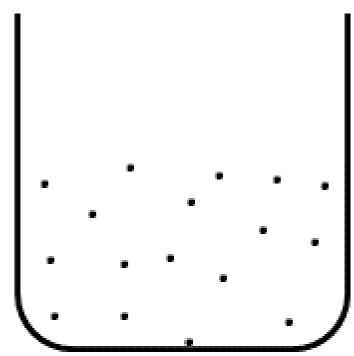
Task 1: Compressing air in the syringe and pumping air out of syringe		**Duration: 30 minutes**
Engage	Teacher reminds learners of their experience with a bicycle pump. Teacher draws a syringe and describe how to pump and ask learners to draw the syringe. Teacher tells learners of how hard it will become to push pump inside with the mouth closed.	Learners listens to teacher. Learners copy the drawing in their books.
Explore	Teacher draws another syringe before pushing the pump.Teacher draws air in both syringe. Teacher writes notes on the board describing what happens to the air when syringe is pushed in and when pulled out.	Learners copy drawings done by teacher showing the two syringe and the air inside them. Learners copy notes in their books
Explain	Teacher explains the arrangement of air in the syringe before pushing pump and after pushing pump. Teacher writes notes on the board for learners	Learners accept what the teacher says without much questioning or reasoning. Learners sit and listen.
Elaborate	Teacher encourages learners to copy notes and drawings in their books. Teachers shows learners how air is arranged Teacher reminds learners that air is made up of particles.	Learners copy correct names of the shapes. Learners listens to teacher but some learners may be not paying attention. Learners take down the notes
Evaluate	Introduces new ideas and facts. Promotes open-ended discussion unrelated to the concept.	Learner response using ‘yes’ or ‘no’ without justification. Offers memorized answers and may read the notes. Cannot give justification of his answer.

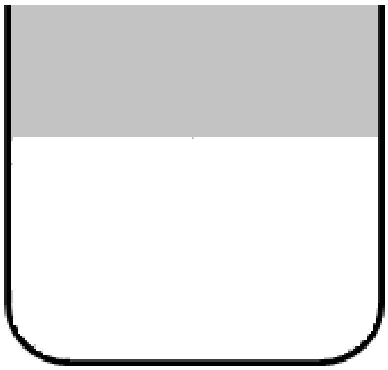
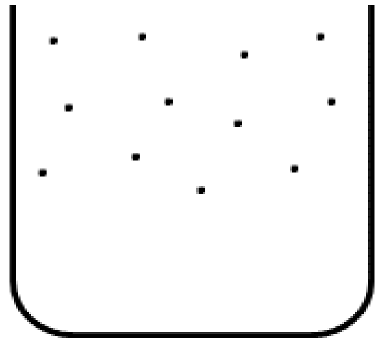
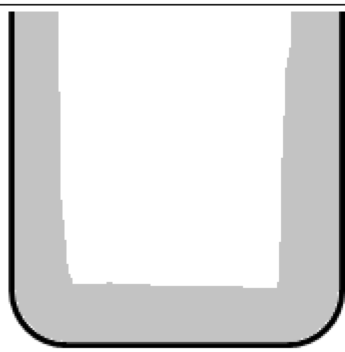
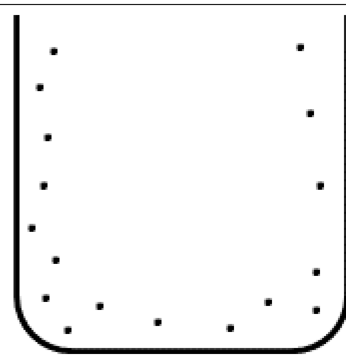
Lesson 2: Compression and expansion of air

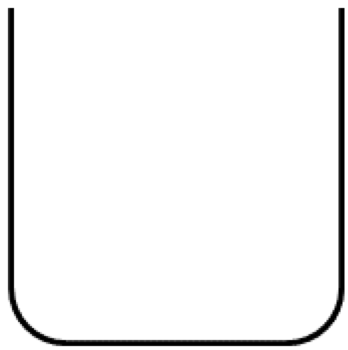
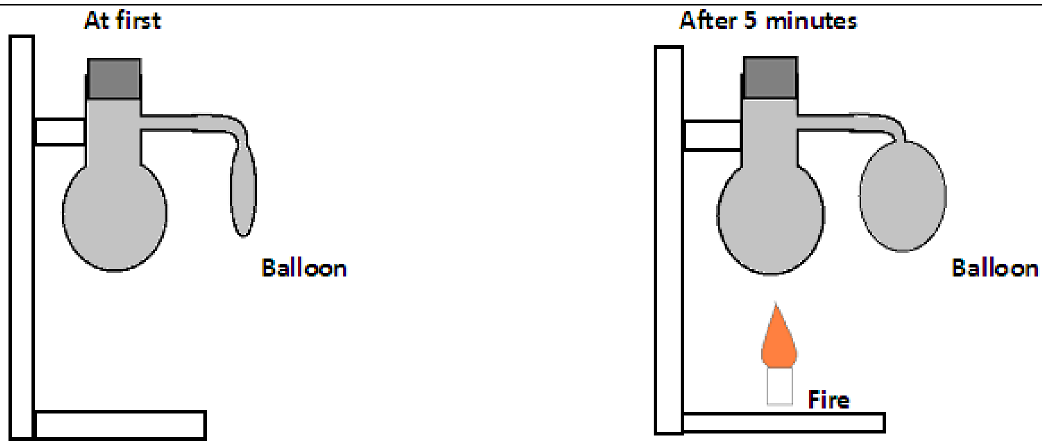
Task 2: Expansion of gases by demonstration		**Duration: 30 minutes**
Engage	Teacher draws the apparatus of a round bottomed flask with lateral tube on a stand with a balloon tied to the end of the lateral tube and a stopper fitted at its mouth. Teacher describes that a burner is placed under the flask to heat the air inside. Teacher asks learners to draw the apparatus.	Learners examines the teacher's drawing of the apparatus. Learners copy the drawing into their books.
Explore	Teacher draws air in the flask and the balloon before heating and after heating. Teacher writes notes on the board describing what happens to the air before heating and after heating.	Learners copy drawings done by teacher showing the flask and balloon, before and after heating. Learners copy notes in their books
Explain	Teacher explains the arrangement of air in the flask before heating and after heating. Teacher writes notes on the board for learners	Learners accept what the teacher says without much questioning or reasoning. Learners sit and listen.
Elaborate	Teacher encourages learners to copy notes and drawings in their books. Teachers shows learners how air is arranged Teacher reminds learners that air is made up of particles.	Learners copy correct names of the shapes. Learners listens to teacher but some learners may be not paying attentionLearners take down the notes
Evaluate	Introduces new ideas and facts. Promotes open-ended discussion unrelated to the concept.	Learner response using 'yes' or 'no' without justification. Offers memorized answers and may read the notes. Cannot give justification of his answer.

Appendix XI: Coding Scheme for the pre-test and post-test

Based on the responses of the learners to the test items, the responses shall be classified as representing continuous model or the particulate model. In each of the models the conceptions of the learners shall in future be classified as particulate, continuous particulate, continuous animistic, continuous empty model, the empty model or continuous model.

Test item	Continuous model representation	Particulate model representation
1	 Learner has a continuous model conception with the idea that air fills the whole container.	 Learner has a particulate nature conception with the idea that air fills the whole container.
	 Learner has a continuous model conception with the idea that air settles at the bottom of the container leaving an empty space at the top of the container.	 Learner has a particulate nature conception with the idea that air settles at the bottom of the container leaving an empty space at the top of the container.

	 Learner has a continuous model conception with the idea that air rise to the top the container leaving an empty space at the bottom of the container.	 Learner has a particulate nature conception with the idea that air rise to the bottom of the container leaving an empty space at the bottom of the container.
	 Learner has a continuous model conception with the idea that air is confined at the walls of the container leaving an empty space at the centre of the container.	 Learner has a particulate nature conception with the idea that air is confined at the walls of the container leaving an empty space at the centre of the container.

	 Leaner may leave the container blank. This may indicate that the learner suggests the container is empty so it’s a vacuum without anything inside. The learner may not recognise gas as to occupy space.
2	 The learner has a continuous model conception. The learner understands that gas occupies the whole container. The gas seems to have increased in quantity due to fire.

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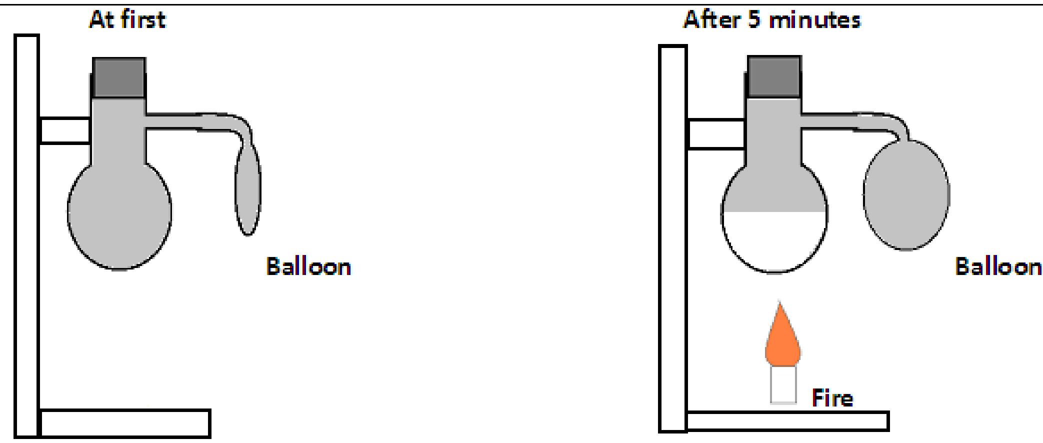

The learner has a continuous model conception. The learner has an animistic idea that gas away from fire.
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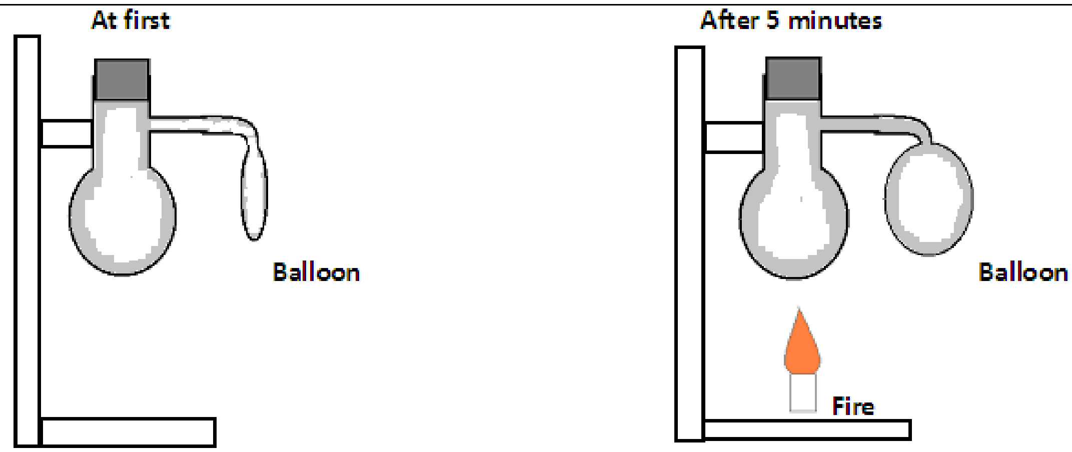

The learner has a continuous model conception. The learner also thinks that gas is only confined on the sides of the container and in the centre is a vacuum. The learner also assumes that a balloon is empty before inflating.
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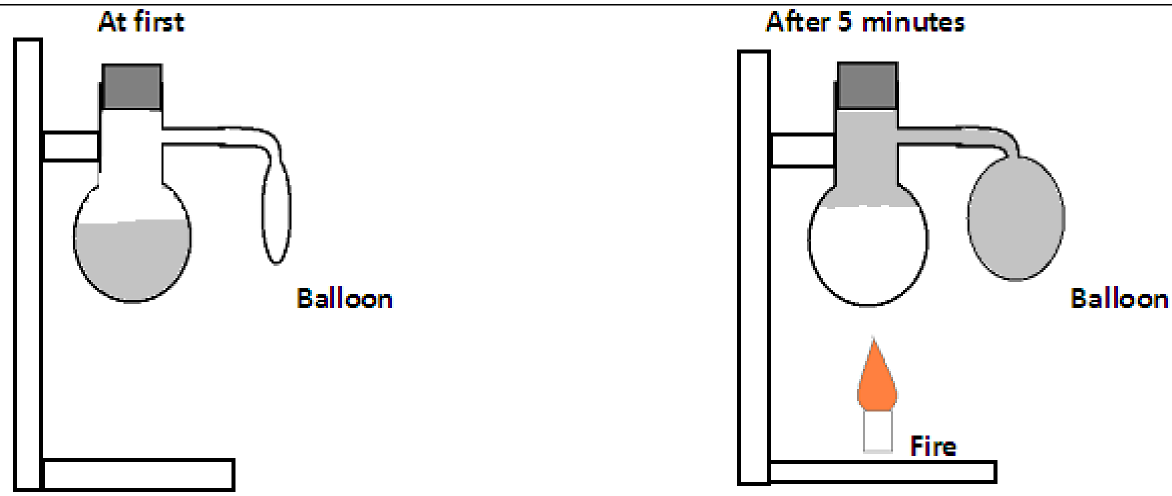
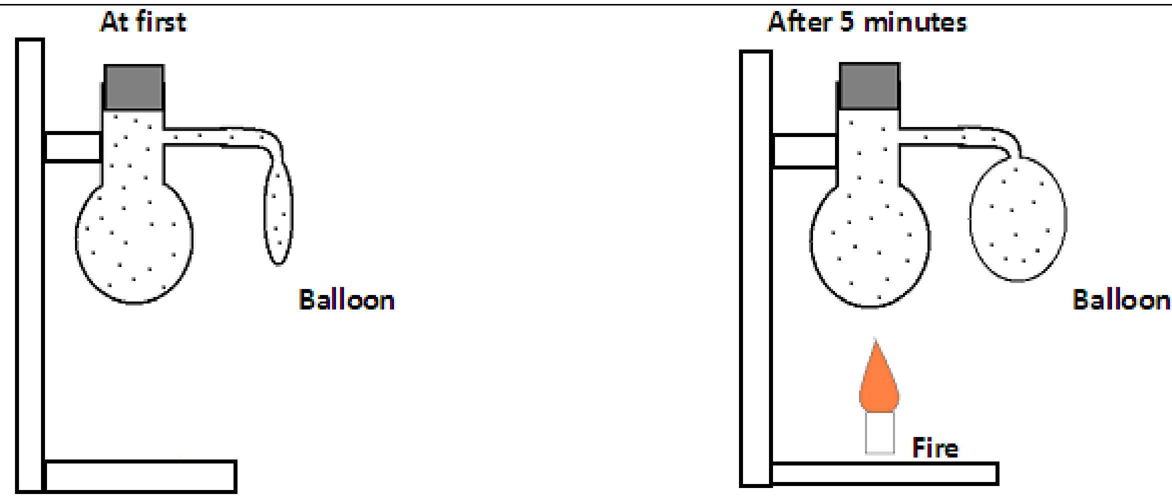
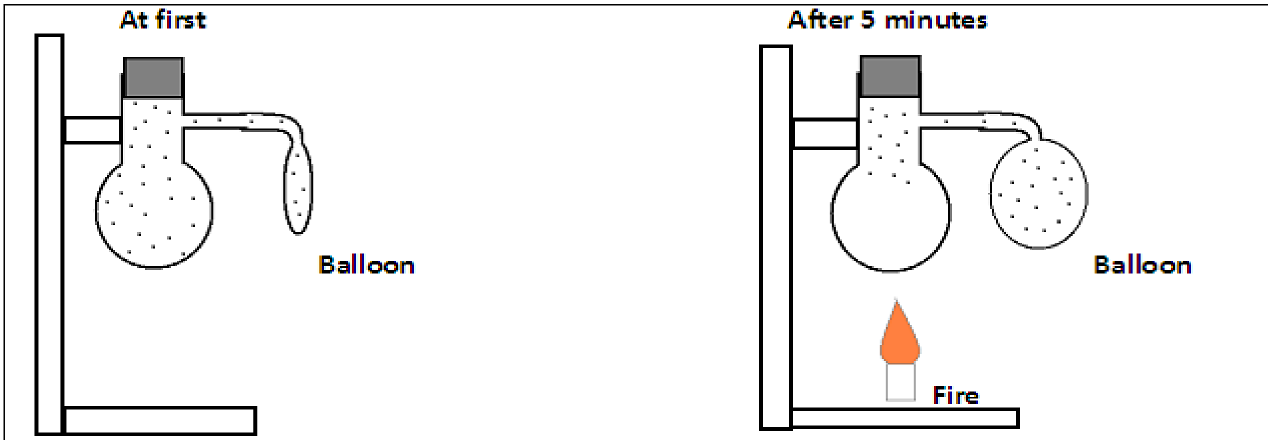


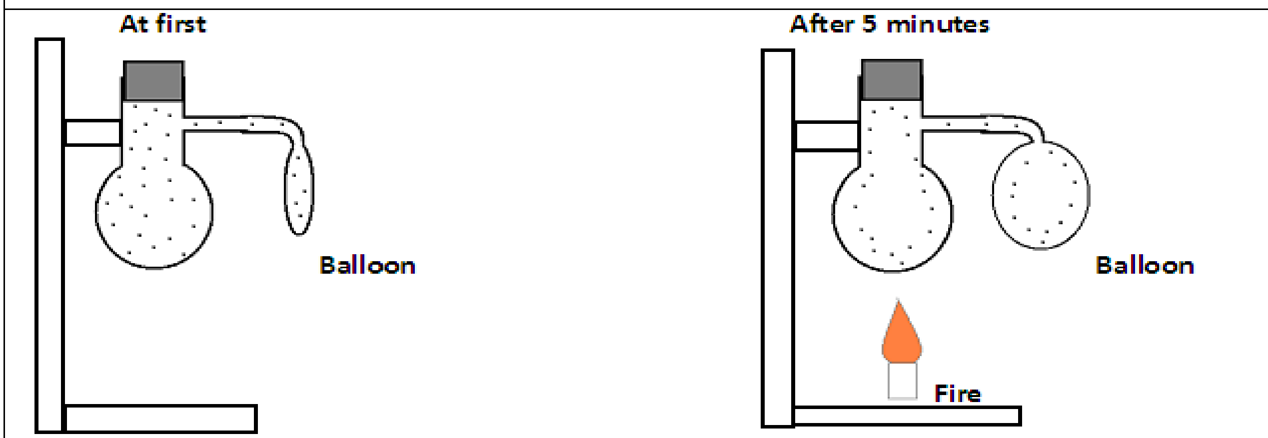
The learner has a continuous model conception. The conception is also animistic in the sense that at first the air particles are like resting at the bottom. When heat is applied the air 'ran away from the fire', by rising up.



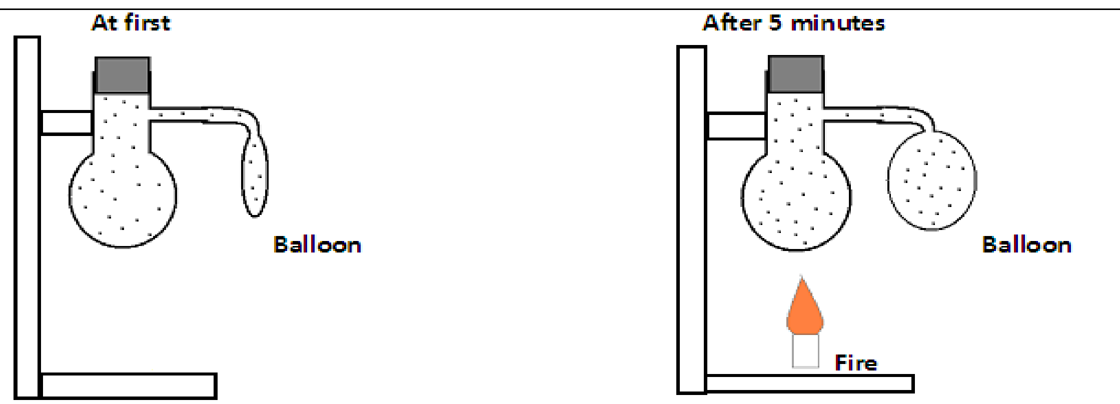
The learner has a particulate model conception. The air particles shown by dots have empty spaces between them. The particles are evenly distributed in both containers. The increase in space between particles resulted in a higher volume after 5 minutes.

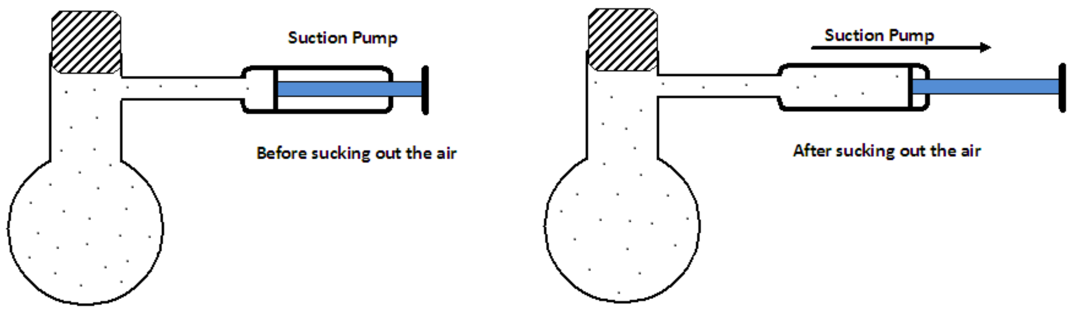


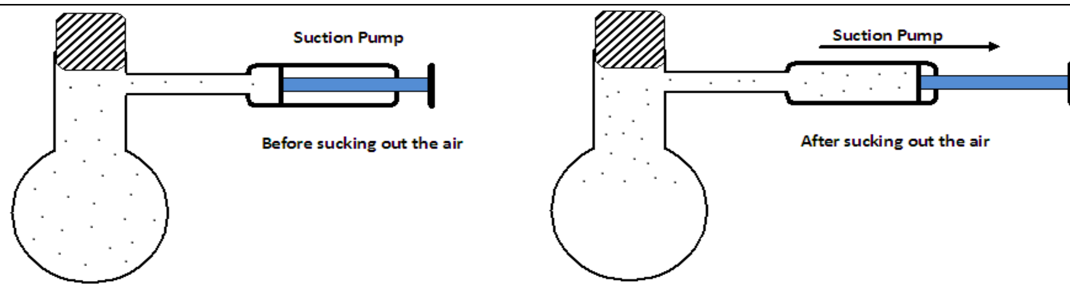
The learner has a particulate conception since the air particles are represented by dots. The learner has an animistic conception of the particles of air since in the second diagram there is an empty space at the bottom.

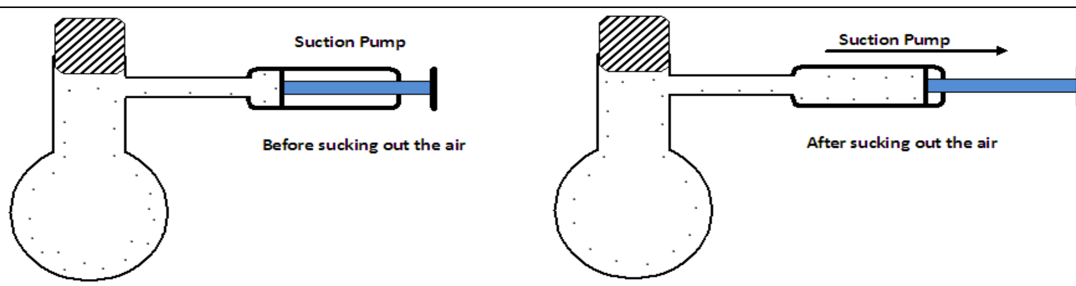


The learner has a particulate conception since the air is represented by dots. The learner has a conception that air particles are only confined at the walls of the container. And that there is a vacuum at the centre.



<table>
<tr><td></td><td>The learner has a particulate conception. The learner understands that air occupies the whole container. The air seems to have increased in quantity due to fire.</td></tr>
<tr><td>3</td><td>

The learner has a particulate conception since the air has been represented by dots with empty space between dots. Before and after sucking the air particles are more or less evenly spaced. There is almost same number of dots indicating that no air was lost.</td></tr>
<tr><td></td><td>

The learner has a particulate conception since air is represented as dots. The suction pump seems to have drawn the air upwards. This indicates an animistic idea that air is leaving the bottom of the container because it is being sucked upwards. CODE: PA</td></tr>
<tr><td></td><td>

The learner has a particulate conception since air is represented by dots. The learner believes that air is only confined at the walls of the container with a vacuum at the centre.</td></tr>
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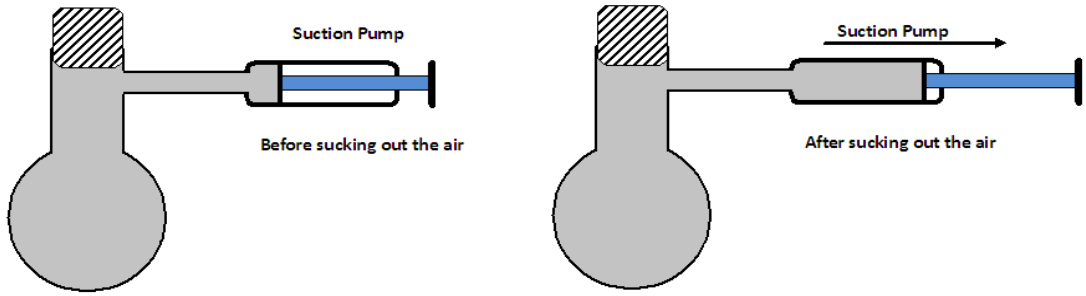

The learner has a continuous model conception since air is represented by shading. The amount of air seems to have increased.
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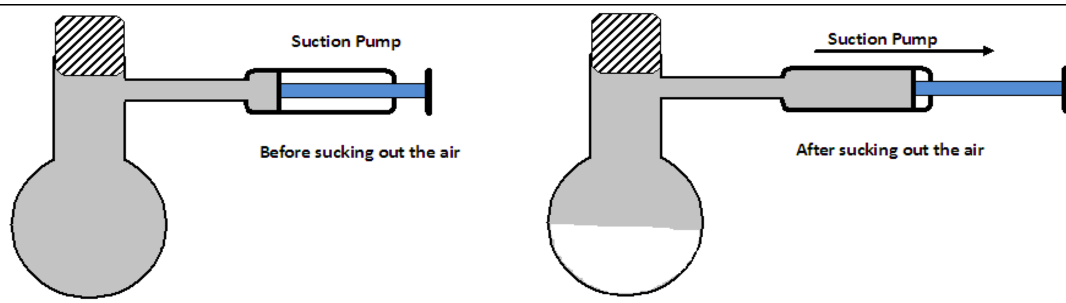

The learner has a continuous model conception since air is shaded. The learner seems to have an animistic idea that since air is being sucked upwards then it goes up leaving a vacuum at the bottom.
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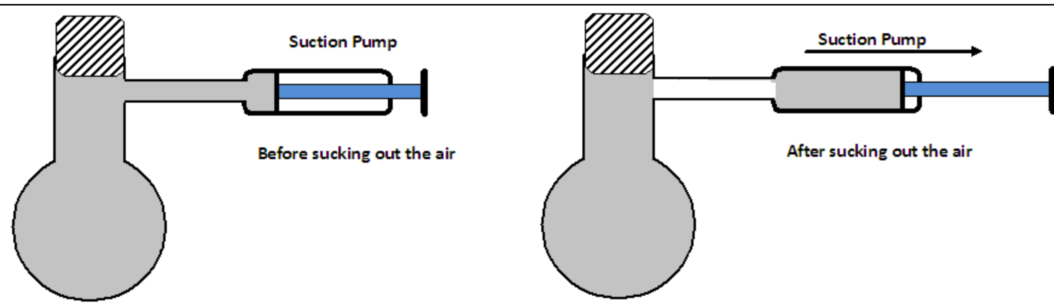

The learner has a continuous model conception since air is shaded. The learner seems to have an animistic idea that since air close to the sucking pump is only sucked, leaving a vacuum between the pump and the rest of the air in the flask.
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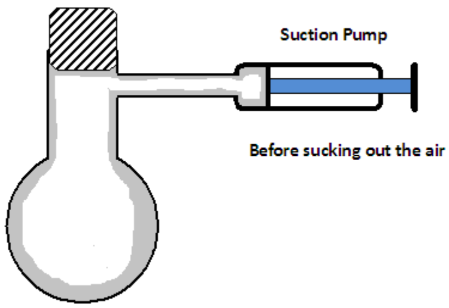

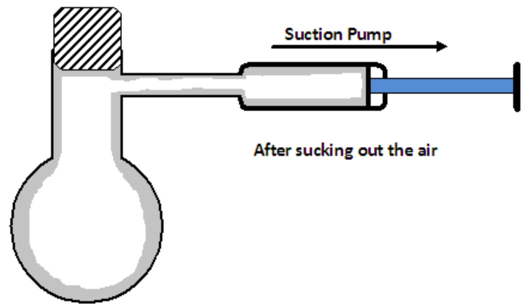

The learner has a continuous model conception since air is represented by shading. The learner also has an idea that air is only confined to the walls of the container leaving a vacuum in the centre.
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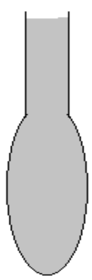
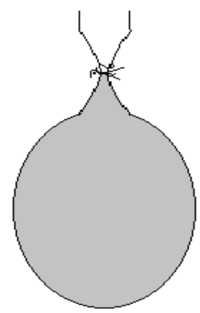
<td>4</td>
<td>
Balloon before blowing air Balloon after blowing air


The learner has continuous model conception since the air has been represented by shading. The amount of air has increased.
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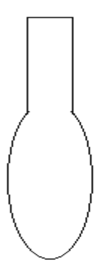
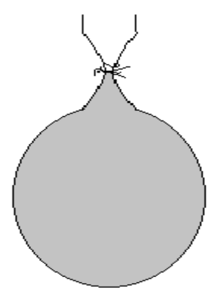
Balloon before blowing air Balloon after blowing air


The learner has a continuous model conception since the second balloon is shaded. The learner believes the first balloon is empty.
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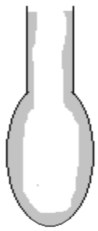
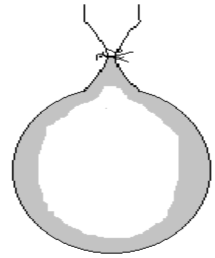
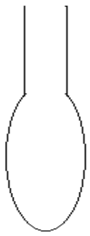
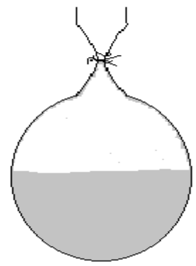
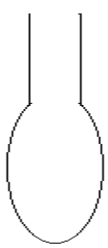
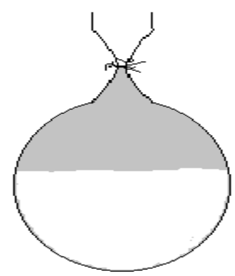
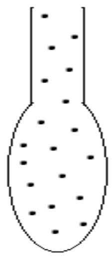
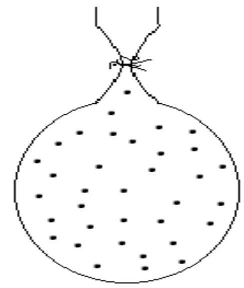
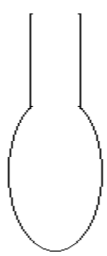
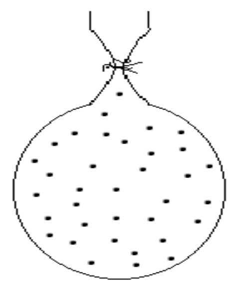
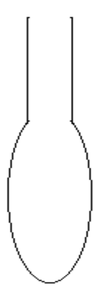
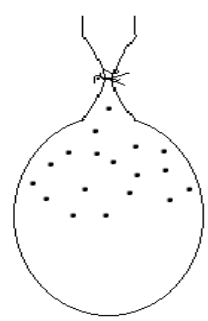
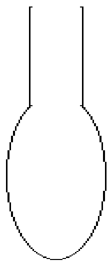
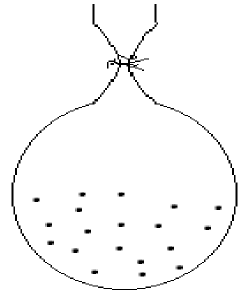
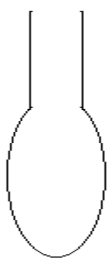
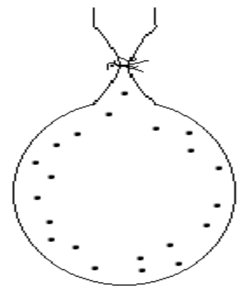
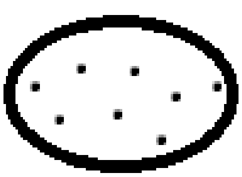
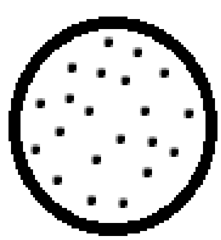
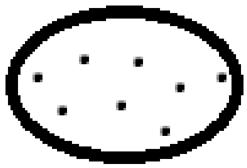
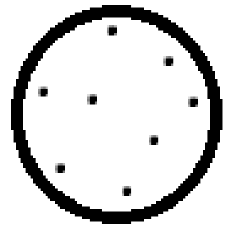
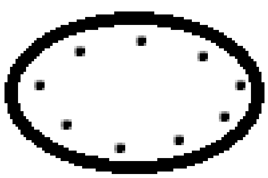
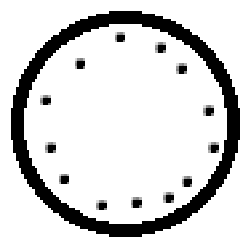
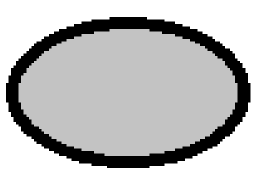
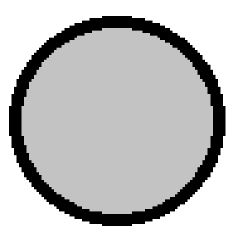
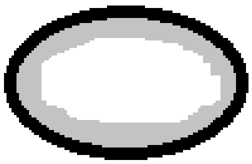
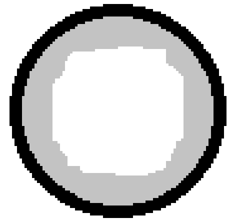
	Balloon before blowing air **Balloon after blowing air**   The learner has continuous model conception since air is shaded. The learner believes the air is only confined to the sides of the balloon leaving a vacuum in the middle.
	Balloon before blowing air **Balloon after blowing air**   In continuous empty model the learner makes a shaded drawing showing air only at the bottom. The other balloon may be empty or similarly shaded.
	Balloon before blowing air **Balloon after blowing air**   The learner has a continuous model conception since air is represented by shading in the second balloon. The learner has an assumption that the air will be confined upwards leaving a vacuum at the bottom. The first balloon is

	considered empty.
	Balloon before blowing air **Balloon after blowing air**   The learner has a particulate model conception since air is drawn by dots signifying particles. The first balloon is not empty and the second balloon has more air than the first.
	Balloon before blowing air **Balloon after blowing air**   The learner has a particulate model conception since there are dots in the second balloon. The learner thinks the first balloon is empty.
	Balloon before blowing air **Balloon after blowing air**   The learner has a particulate model since the second balloon shows dots of air. The learner thinks the first balloon is empty and also that the air is only confined

	to the top and a vacuum at the bottom of the balloon.
	Balloon before blowing air **Balloon after blowing air**   The learner has a particulate model since the second balloon shows dots of air. The learner thinks the first balloon is empty and also that the air is only confined to the bottom (resting) and a vacuum at the top of the balloon.
	Balloon before blowing air **Balloon after blowing air**   The learner has a particulate model since the second balloon shows dots of air. The learner thinks the first balloon is empty and also that the air is only confined to the walls of the balloon and a vacuum in the middle of the balloon.
5	**Ball with less air** **Ball with much air**   The learner has a particulate model since both balloons show dots of air. The first balloon has less air than the second.

	Ball with less air **Ball with much air**   The learner has a particulate model since both balloons have dots to represent air. The learner believes that the same amount of air is in the ball since the number of dots is draw
	Ball with less air **Ball with much air**   The learner has a particulate model since both balloons have dots to represent air. The learner believes that the air is only confined around the walls of the ball leaving a vacuum in the centre.
	Ball with less air **Ball with much air**   The learner has a continuous model conception since both balloons have been shaded to represent air. The second picture shows that the ball has more air.

	Ball with less air  **Ball with much air**  The learner has a continuous model conception since both balloons have been shaded to represent air. The learner believes that air is only confined along the walls leaving a vacuum at the centre.

Appendix XII: Letter of permission to do fieldwork

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Education

Faculty of Education
Ethics Committee
3 June 2014

Dear Mr. Mamombe,

REFERENCE: SM 14/02/01

We received proof that you have met the conditions outlined. Your application is thus approved, and you may **continue with your fieldwork**. Should any changes to the study occur after approval was given, it is your responsibility to notify the Ethics Committee immediately.

Please note that this is **not a clearance certificate**. Upon completion of your research you need to submit the following documentation to the Ethics Committee:

1. Integrated Declarations form that you adhered to conditions stipulated in this letter – Form D08

Please Note:

- *Any amendments to this approved protocol needs to be submitted to the Ethics Committee for review prior to data collection. Non-compliance implies that approval will be null and void.*
- *Final data collection protocols and supporting evidence (e.g.: questionnaires, interview schedules, observation schedules) have to be submitted to the Ethics Committee before they are used for data collection.*
- *On receipt of the above-mentioned documents you will be issued a clearance certificate. Please quote the reference number **SM 14/02/01** in any communication with the Ethics Committee.*

Best wishes,

Prof Liesel Ebersöhn
Chair: Ethics Committee
Faculty of Education

Appendix XIII: Letter of informed consent for educators

Tshwane Christian School

P. Bag X03
Onderstepoorte

0110

Cell: 074 299 6108

Date ....

Dear Educator:

RE: **<u>REQUEST FOR YOUR PARTICIPATION IN THE STUDY AT YOUR SCHOOL</u>**

I am a student in the Department of Science, Mathematics and Technology Education at the University of Pretoria, doing a research study entitled **"***The influence of Inquiry-Based Science Education on grade 4 learners' understanding of particulate nature of matter in the gaseous phase.*" I am requesting for permission to collect data at your school.

The aim of the study is to identify the influence of inquiry based science teaching and the teacher-centred approach on grade 4 learners' understanding of the particulate nature of matter in the gaseous phase. Two grade 4 classes at your school shall be given an initial test and shall be taught by two experienced educators in the presence of the usual class educator for two lessons. Each experienced educator shall teach one class using the inquiry based approach and the other experienced educator shall teach using the teacher-centred approach. After the two lessons the two classes shall write a second test similar to the first one.

I hereby ask for your consent in participating as one of the grade 4 educators at your school. If you agree to participate you may be required to observe the lessons offered to your class by one of the experienced educators. And you you may be interviewed after the intervention.

All information related to the study will be treated anonymously when reporting results. The identity of participating schools, educators and learners will be strictly confidential. Your positive consideration of our request will be highly appreciated. Should you agree, please read and sign the attached consent form. Thank you very much for spending time to consider this request.

Kind regards.

Signed : .... Date...................

Mr. Mamombe C. Student number 12293581

Informed consent form for data collection

Please read the conditions below and sign if you agree that your school may participate.

With reference to the request for permission to conduct research entitled: **"***The influence of Inquiry-Based Science Education on grade 4 learners' understanding of particulate nature of matter in the gaseous phase.*" I understand and agree that:

- Two grade 4 classes at my school shall write a pre-test which last for about ten minutes.

- Two grade 4 classes at my school shall be taught for two lessons by an experienced educator in the presence of the usual educators.
- Data shall be collect before, during and after the teaching.
- Data collected will only be used for research purposes.
- The identity of the school, educators and learners will be held in the strictest confidence.
- This school's participation in the project is voluntary, and the school can withdraw at any stage of the research.
- I am not waiving any human or legal rights by agreeing to participate in this study.
- I verify by signing below that I have read and understood the conditions listed above.

Educator's Signature: ....

Place and date: ....

Student's name: Mamombe Charles Signature: .... Student number: 12293581

Place and date: ....

Supervisor's name: Mrs. Mathabathe K. **Signature**: .... **Place and date**: .University of Pretoria, 08/03/ 2014.

If you have any questions about this research project, please contact Mrs. Mathabathe K. (Supervisor) by telephone on 012 420 2758 or email kgadi.mathabathe@up.ac.za.

Appendix XIV: Interview for first educator

I: Okay, good morning Ma'am?

P: Good morning sir.

I: We want to do an interview on.. to find out your observations in the inquiry lesson that we just had about a week ago. Now with regards to the inquiry lesson, in your class here, what issues to you notice about the learners' activities and their participation during the lesson?

P: Learner participation was very good, the children were not passive, they were actively involved in the activities, ……(interruption) they were actively involved in the activities, and now I am repeating myself. I , I , I think …. It was successful as far as learner participation is concerned.

I: Okay. So it means there were a lot of activities that the learners were doing?

P: Yes, yes the learners were actively involved all the time and the paid great attention.

I: Okay, and to your own understanding how do you think the learners might have understood the content?

P: definitely understood the content. Even the weaker children because there was a number of activities covering the same topic, and by the end of the lesson the weaker children had grasped the new concept.

I: Okay. So you are saying this method, the inquiry method offers learners with activities which make them understand the content?

P: Yes, exactly. They need to be actively involved, they need to make discoveries for themselves.

I: Okay. Now with regards to the time taken to do the inquiry lesson, during the teaching, what can you say about the time taken to finish the lesson? Is it the same time as the lecture method, is it less or what?

P: There are constraints in the classroom. One has got an hour, an hour and a half time to do your lesson, I think she stayed within the parameter of one and half hour lesson which is required.

I: Okay. I mean in general, how this method of teaching, the inquiry method, do you think it requires more time for the learners to do their activities, or it requires the same time (as lecture method)?

P: It needs more time, it needs more time, so I think should be adjusted.

I: And in connection with the resources, do you think if are asked to teach using the same method, do you think you have enough resources to do the lesson?

P: I myself will bring the resources to the classroom to do the lesson to ensure that it is successful. If the school cannot provide the necessary resources, I feel it is the teacher's responsibility to make sure that she/he provides the resources to have a successful lesson.

I: And what reason do you think is behind that, you say you can find the resources? Is it because that the resources can be easily found …

P: Yes, for that particular lesson the resources are easy to find. Actually the learners could have brought some of the resources themselves as well. Because they were very, day to day materials the children were familiar with. The children could bring them and help the lesson to succeed.

I: Okay, on that regard, what do you think are some advantages of the inquiry method which are related to the learner's understanding of the content, if you can mention any advantages?

P: Remember the old say. *"if you do you remember?*"

I: Yes.

P: That's definitely a great advantage for the learners. They obviously need to be guided by the educator, but by doing the actual inquiry method themselves, definitely assist them to understand the content of the lesson.

I: Okay. And any disadvantages?

P: It is time consuming, but I personally believe something thoroughly using the inquiry method than to rush ahead and the children don't understand the concepts. That's the only disadvantage I feel the time factor.

I: okay, to just recap the whole interview, do you have any other observations apart from what we have said, what you may have observed? Which you might want to highlight?

P: Aah, a positive observation is that, the children the need to use kinetic energy that means the children that need to use aah!..

I: The motor skills?

P: Yaa, they were all involved, they ones that are more introverted they tried to participate and once they made discovery they felt part of the lesson and they were more actively involved in answering questions, which was really, really very encouraging.

I: Okay. And any recommendations that you may put maybe?

P: Regarding the inquiry lesson?

I: Yes.

P: Please speak to the education department and tell them to re-look at the curriculum and so that less can be taught more thoroughly using this fantastic method. I was very impressed with the lesson and I think the children really benefited from it.

I: Alright. Okay. Thank you very much, thank you for your time.

P: That’s okay.

Appendix XV: Interview for second educator

I: Good afternoon Ma am.

P: Afternoon Sir.

I: We want to have a discussion over what happened during the inquiry lesson, in you class as you observed during that class.

P: Okay.

I: The first question will be, when you were looking at the learner activities, what activities did you see the learners doing which, which you can say I observed, I noted something on the activities?

P: Right on that activity I noticed that most of the activities I needed to have done it. For the activities you have done I noticed that it was interesting because most of the activities I have done them in my class. So you did something new for them.

I: Okay. And what can you say about the learners' participation in the lesson?

P: Right, Yah, it was team work and they were more involved.

I: Okay. And what can you say about that involvement? What do you think is the advantage of the learners being more involved?

P: Right, what I have realised is that most of the learners who were passive because they depend on others. Those who were slow learners they start to depend on others but the ones who were good really the performance was good.

I: So the learners were actively participating?

P: Right, they were active.

I: So how do you think this might impact on the understanding of the learners?

P: Right, it was difficult for them because some of the questions, were so.. ., it was tricky for them. Because as one of the learners who has asked you that 'some of the content is not accessible enough, so how can you ask me that question?'

I: Yes

P: Yah it was tricky but at the end they realised that oh this is what we had to learn.

I: So it means at the end of the lessons did the learners understood the lesson or ..?

P: Yes, yah yah, they did understand the lesson.

I: And now on the issue of time. How can you say how was time managed?

P: Right, on coming to time, you have to know that the grade 4s are too slow. They need to have a lot of time. So for me I think the time was no enough for them.

I: The time was not enough?

P: Yes. They need more time. Especially when they observe something they need something practical on what they observe. So time was not enough.

I: Yes. Okay, and the resources used in the class do you think they were useful to the learners?

P: Yah. When coming to resources it was perfect because when you included those apparatus it gave excitement. At least you gave us something new.

I: Okay. Would you think if you were asked to have such a lesson, do you think you would have enough resources to use in such a kind of lessons?

P: Yah, I will.

I: Okay. And what advantages can you sight in the use of the inquiry method?

P: The advantage is that the pupils will be able to understand clearly and they will be able to answer the questions as long as they have the apparatus. It's easy for them to engage themselves in the content.

I: Okay. And do you have another advantage that you might have noticed?

P: Ah! To tell the truth. No. everything went well.

I: Okay. And any disadvantages of the method?

P: Disadvantages? No. everything was smooth really.

I: Alright.

P: Everything was perfect.

I: Do you have any other observation apart from what I have asked you? Did you observe anything else?

P: Yah. I observed that learners as long as they work in groups, some of the learners can be able to learn more from others. And the method created a positive atmosphere.

I: Okay. I remember during the first day I came here. That girl who said, when I gave out the pre-test, who said this doesn't make sense.

P: (laughs).

I: But at the end she was very interested.

P: Yah. I still remember that.

I: So, what can you comment about that observation?

P: Yah, at first they did not understand what you were going to teach about. And at the end they were at a good position to understand.

I: And so do you have any recommendations?

P: Well done, hundred percent. Everything went well really. Even me as the teacher I have learn more.

I: Okay. So in future would you want to try the method in one of you lessons?

P: Yah, as long as you can borrow us apparatus. Because I cannot try it without apparatus. Supply us with apparatus.

I: Okay. Thank very much for your contribution. May God bless you.

P: Thank you sir.

Appendix XVI: Initial group interview school A inquiry class

Note: At School A every male beyond school going age including, teachers are “uncles”, and every female who is above school going age is known as “auntie”. So the researcher is addressed as Uncle Charles.

I: Yes, good morning boys and girls.

P: Good morning Uncle Charles (chorus)! Uncle Charles

I: Yes. I see you have drawings here! What is? Wow, this is your drawing?

P: Yes, Uncle

I: Can you tell me why you drew it like that?

P: Uncle, I drew it like that because they say we must draw the air… when the air comes … in the air .. in the beaker.

I: Why did you not draw it like this?

P: Uncle I think it gets out.

I: Oh, it is getting out?

P: Yes

I: Is it getting out?

P: Yes Uncle.

I: And

P: It is getting out.

I: And here?

P: It is getting in.

I: It’s getting in?

P: Yes

I: This one is getting in?

P: It’s getting out.

I: It’s getting out? And what happened here?

P: Here the balloon the air and here we can blow the balloon

I: So this one has air inside?

P: Yes, and it’s getting out to go to the balloon.

I: To go to the balloon?

P: Yes

I: And so, what happened here?

P: Here, when you look from that side the balloon has got air, so that air go into the balloon.

I: Does it leave the glass bottle?

P: Yes

I: So it goes to the other side?

P: Yes

I: Okay. And yours? What happened here?

P: I draw the air inside here. I draw the air and it went to the balloon.

I: It went to the balloon because of what?

P: Because of the fire is heating the air.

I: It’s heating the air?

P: Yes

I: And what about here I see the it’s empty here, the balloon?

P: There is no fire that can heat the air.

I: Because there is no fire this side?

P: Yes, eish!

I: Okay. And let’s see the next page, that’s question 3. Let’s start with him. Here I see you did not draw any air here?

P: Yes, because.. I didn't draw air because the pump is not pulled so it block the air cant escape.

I: And here you draw the air?

P: I drew the air coming out because the pump is open.

I: And it is now pulling it (air)?

P: Yes.

I: Okay. And here?

P: Here I drew the inside there inside the container because the air inside the balloon because the air will come out.

I: Okay. Lets go to the next question. Question number 4. My friend, what happened? Why did you draw it like this?

P: Because it is getting into the balloon.

I: Oh, because the air is getting into the balloon?

P: Yes

I: Okay, and here?

I: It's getting in and its getting in? and you?

P: Yes Uncle.

I: I see there is no air there?

P: Yes Uncle. The air is coming, the person is blowing in the air so that it can be big, and the air is now outside here. There is no more air.

I: But the balloon is now big? Why is it big if there is no air?

P: Uncle it's getting through, it's blocked. The thing is blocked here and the air can't get through.

I: Okay. And you?

P: Uncle, after blowing the balloon the air is still in there because they close the balloon.

I: Because they close the balloon?

P: Yes Uncle

I: So how do you compare the balloon when there is air and the balloon before blowing?

P: There is much air than before blowing.

I: Okay. Let's go to the last question. Let's go to the last question. How did you, why did you draw it like this?

P: Because there is less air in the ball.

I: Yes

P: And here there is much air in the ball.

I: But here in the second ball there is no air at the top. Why?

P: mumbling

I: Because what is the air doing there? Is the air only at the bottom?

P: Yes. The air is only at the bottom and not at the top.

I: Not at the top?

P: Yes

I: And here?

P: Here there is air. The air comes round and round and round so that in the middle there is no air. It goes around and share the room. Now the air comes inside the middle and round and round round round.

I: Okay. And you?

P: Uncle, the air is blocked down there.

I: Okay. The other ball has much air?

P: Yes.

I: Okay, and here?

P: Here there is less air. The air in this ball is less because it's not round its oval.

I: But tell me. I see you have drawn the air up at the top here and at the bottom there is no air. Why?

P: Here there is more air at the top than at the bottom.

I: So there is more air at the top than at the bottom?

P: Because when you pump the air comes in at the top.

I: Okay. All right. Thank you very much for your drawings and for your answers.

P: Thank you Uncle Charles (Chorus)

I: Okay.

Appendix XVII: Initial group interview school A lecture class

Good morning boys and girls.

P: Good morning Uncle Charles (Chorus)

I: Yes, I am glad you have drawings here and am seeing they are different drawings that are here.

P: Yes

I: Can you tell me why did you draw it like this?

P: Because where there is circles there is no air and where there is no circle is the air.

I: So the circle is the air?

P: No.

I: Yah

P: When there is no circle its air.

I: And where there is circle?

P: It's when you do not have air.

I: And here?

P: Here when the wind comes and the water goes at the side.

I: Yes. I see you have put dots inside there. Why did you do that?

P: Because Uncle when the wind comes blowing there and the water goes there where the wind goes.

I: Okay. And I see here you have drawn lines like this. What does that mean?

P: Uncle…. It shows there some air between us.

I: There is some air between us?

P: Yes

I: Okay. And here?

P: when the air blows in the water goes up.

I: Okay. And here?

P: Uncle when you blow up the water Uncle, when you blow hot water uncle, when the hot water is blowing uncle there is air coming out uncle.

I: Alright. Let's look at the second question. Here we are still there. Here. (Showing learners the question). I see this one is empty. Why is it empty?

P: It's empty because i did not blow the balloon.

I: You did not blow the balloon?

P: Yes

I: And here on the second one?

P: This one has air.

I: Where did it come from?

P: I blew it.

I: You blew it?

P: Yes

I: But we never said you must blow. And you blew it.

P: I drew it

I: You drew it?

P: Yes

I: Okay. And here I also see it is empty, why?

P: Because there is no air in here.

I: There is no air?

P: Yes

I: And here there is air?

P: Yes because this fire is making this, this balloon being full of air.

I: So is the fire putting air inside?

P: Yes

I: Okay. And then here?

P: Here the fire is picking up steam and the steam is heating up.

I: So steam goes into the glass bottle?

P: Yes.

I: Right. Let's go to the second, the next page. Let's look at the second page. Answering here. I see this one you have drawn it full with lines up to there. And this one there is no lines there. Why?

P: Uncle this one it is because there is air pumping up in here.

I: Yes

P: And then in here they took away the pump and the air can't go in again.

I: The air can't go in again?

P: Yes. They took away the pump.

I: And here?

P: It's full here because there is air pumped in and here it is not full because they pumped it out.

I: They pumped it out.

P: Yes.

I: And here?

P: Uncle in here there is uncle. There is air in here because uncle they closed it. And here uncle it's only a little air uncle because it was open uncle.

I: It was open?

P: Yes

I: Okay let's go to the interesting one question 4. Here I see there is little air in the first balloon. And this one seems to have a lot of air. Why?

P: Because this one is not pumped, and this one they pumped and they closed it because they don't want it to go out.

I: To go out?

P: Yes

I: And here?

P: Here they pumped the balloon and tied it because they don't want the air to get out.

I: To go out?

P: Yes

I: But what this space mean? Where there is no circle, like this space?

P: It means its air.

I: Its air?

P: Yes

I: What do the circles mean?

P: When you put your hand there.

I: When you put your hand there?

P: Yes

I: And here what this mean?

P: Even though you did not pump the balloon but it will have a little air inside.

I: It will have little air before we pump it?

P: Yes uncle

I: And here?

P: And here it has been blown up so it full air inside.

I: So this is how the air looks like? With like lines like that?

P: Yes uncle in my imagination.

I: Alright. And I think this one is the same like that one. So I won't ask again that one. Let's go to the last question. The last question. Here. Let me see here. Yes, you drew like this with air on the sides only and also at the centre?

P: It’s on the circles and at the centre but it’s not that much air.

I: Okay. Why?

P: Because umm the ball is almost flat.

I: The ball is almost flat?

P: Yes.

I: On the other ball?

P: Because the ball is full.

I: Alright.

P: Yes

I: And here?

P: Uncle this one uncle, there less air in this one because the ball has been pumped down. And uncle there much air in here because it is pumped up.

I: Here is see there is something interesting here. I see you drew air at the top and not at the bottom. Why?

P: Uncle, at the top there is lot air and at the bottom there is less air.

I: Why?

P: Because the balloon is punctured.

I: So it is puncting at the bottom only?

P: No uncle the air is puncting. (Puncting means punctured in this context)

I: Alright. Okay. And so I see here there less air at the bottom than at the top. Why?

P: Uncle because the ball is empty. It’s flattened down. The air will pump out if usually at where is a lot of air is where air is coming out.

I: So where do we have a lot of air?

P: Uncle here in the top.

I: In the top?

P: Yes

I: So there is lot of air at the top than at the bottom?

P: Yes uncle because the air is going up and it's going to get out.

I: What about this one which is full, which side do we have a lot of air? The top or the bottom?

P: Uncle, there is no side uncle.

I: All the sides?

P: Yes uncle, because it's all filled up.

I: It's all filled up. Okay. And there I seen you have drawn, there is less air on the right side. Is it?

P: No uncle, it is the same.

I: It is the same all around the same ball?

P: Yes. But there is no...

I: There is not much air?

P: Yes, because the air is coming out on the ball because there is a, there is...

I: There is a puncture?

P: Yes. There is …. They put on the stick and it popped.

I: Okay.

P: And this one is full because they pop it in.

I: Thank you boys and girls

P: Thank you.

Appendix XVIII: Initial group interview School B inquiry class

I: Okay good morning, young people.

P: Morning sir.

I: Yes, I see you have made drawings here. So I want to ask a few questions about why you drew the diagrams like that. For example, let's start with this one. Why did you draw like this?

P: Because its air.

I: Because its air?

P: Yes

I: Okay, so it looks like that?

P: Yes

I: Because it looks like this?

I: Okay, and you. Why did you draw it like that?

P: Because it's the whole air.

I: It's the whole air?

P: Yes

I: And you. Why did you draw it like that?

P: Because e it's the right air.

I: and on the second question you drew it with the air at the bottom. Right? Why did you draw it like that?

P: Because whn it is on the balloon the air will go up but its right inside.

I: Okay and here now I see the bottle is full. Why is it full.

P: Because we pumped it rightly.

I: How was it pumped?

P: (No response)

I: Did you pump it in?

P: (No response)

I: Did it come from the fire?

P: (shaking of head)

I: No. Okay. And you I see it is like that why?

P: The air is coming on the top

I: The air is coming to the top?

P: Yes

I: From where?

P: From the balloon

I: From the balloon?

P: Yes

I: My friend, you have this one.

P: Yes

I: The air is at the bottom?

P: Yes

I: Why?

P: Because it want to come to this one.

I: It want to come to the balloon?

P: Yes

I: and here now why is it now at the bottom?

P: Because its pumping this one to be full.

I: Its pumping that one to be full?

P: Yes.

I: and why do we have little air here and a lot of air there? Why?

P: We are pumping this one.

I: We are pumping that one?

P: Yes.

I: Using what?

P: Pumping in air

I: Okay, lets go to the second question. Open the next question. Right, I see you have the air up to the neck but here is up to there? Why?

P: Because this one (Pump) is pulling air from the top and this one is pulling the air from the bottom.

I: So this one is pulling the air?

P: (Node) Affirmation.

I: Okay, and here I see you have a lot of air there in the second bottle and few air in the first one. Why?

P: Because air is pumping there (second bottle) but (in the first one) its sucking the air.

I: Its sucking the air?

P: Yes

I: I see there is no air on the left side of the second balloon. Why?

P: Because the air is too ….

I: Is too what?

P: Is below. (Lack of language expression)

I: Is below?

P: Yes

I: And here, I see the air is only at the bottom, why?

P: The pump didn't fill it rightly.

I: The pump didn't fill it rightly?

P: Yes

I: And question number 4 I see the air at the bottom and here I see there is no air here and I see there is little air here. Why is there no air in the first one?

P: The balloon don't have air.

I: The balloon doesn't have air? Why?

P: (No response)

I: Because it is before blowing?

P: Yes

I: Okay and here I see there is little air, why?

P: Because here is when it has little air. When you blow it, it becomes big.

I: It becomes big?

P: Yes

I: And you?

P: When you blow the balloon the air comes from here (glass bottle) to the balloon then it got bigger.

I: Okay.

P: It will …. (Demonstration of increasing in size)

I: Alright. The last question quickly. Lets start with this one. Why is the air at the bottom only?

P: Because the ball is not hard.

I: The ball is not hard?

P: Yes

I: And here is it complete like that?

P: The ball is less (Has less air)

I: The ball is less?

P: Yes

I: And here?

P: The air is less.

I: The air is less?

P: Yes

I: And here?

P: Its, the air is much.

I: Is much?

P: Yes

P: The air is level here the air is much.

I: Alright. Okay, thank you very much

Appendix XIX: Final group interview school B lecture class

I: Okay let's see. How did you. Why did you draw it like this?

P: It is air sir.

I: It is air?

P: Yes.

I: And I see there are circles. Why?

P: They are called micro…. Little ones.

I: Microscopic particles?

P: Yes.

I: Okay. So that's why you drew them like this?

P: Yes sir.

I: Okay and here I see you only drew at the bottom. Why? And it is shaded? Why?

P: It is air.

I: It is air?

P: Yes

I: So it means at the top here there is nothing?

P: no response.

I: Why? Is it sitting at the bottom?

P: No

I: No. Why? So why did you draw it only at the bottom?

P: No response

I: Hmn? You don't know? And here? I see you shaded all around.

P: Yes

I: What?

P: The bottle is full of air.

I: The bottle is full of air?

P: Yes.

I: And what about these things which are like snakes.

P: They are the particular things.

I: The particles?

P: Yes.

I: They are like snakes like this?

P: Yes.

I: Okay. And here you drew dots, dots dots. What does it mean?

P: Its air.

I: Its air?

P: Yes.

I: So these are what? What are they called? The dots?

P: (No response)

I: They are called the particles. Right.

P: Yes

I: And here I see you have dots and also things like snakes. What are they for?

P: They are air sir.

I: It is air?

P: Yes.

I: Okay. And on the second one you drew, it air again, with dots and those strings?

P: Yes

I: Okay

I: And here, my friend listen to me. Why do you have few dots here (in the ball with less air) than in the ball with much air?

P: This one has got a puncture and this one does not.

I: This one has a puncture? So what about the number of dots? Why did you draw a few dots?

P: It has less air.

I: It has less air? Some of the air left?

P: Yes

I: Okay. And here. I see you only shaded the bottom and there is nothing at the top. Why?

P: Because much air got out (in the punctured ball).

I: Much air got out?

P: Yes

I: So the much air got out only from the top?

P: Yes

I: And at the bottom its still there?

P: Yes

I: and at the much air it is full?

P: Yes

I: Here I see you only drew air at the centre. Why?

P: Because this one has a puncture.

I: Has a puncture?

P: Yes

I: So the air only come out at the sides it does not come out at the centre?

P: no response)

I: And here you only drew at the bottom. Why?

P: No response)

I: Does it not have air at the top here?

P: It does.

I: It has. My friend I see these ones now, the circles are now big?

P: Because the air fits in the shape. So the air took the shape of the ball.

I: Alright. And why are circles here small and here big?

P: No response)

I: At the one with less air the particles are small and at the on with much air the particles are big. Why is it big?

P: This one has got a little air.

I: Okay. Right lets go to the next page. Turn your paper to the next page. Right, I see there is no air here. Why?

P: The air is at the balloon.

I: The air is at the balloon?

P: Yes

I: Okay (Interruption). Now I see there was no air here, and now there is air there.

P: Sir the air in here is coming up into the balloon so the balloon is growing bigger.

I: But this is the same thing. Here I see there was no air here and now there is air. Where did it come from?

P: It come from the fire

I: It came from the fire? Okay. And here. It's the same there is are here and also there is air here? And what happened there. What is this at the bottom of the balloon?

P: Its air

I: What is it doing at the bottom of the balloon? Is it resisting at the bottom? What happened? Why did you draw it like that?

P: (No response)

I: Okay. Lets see here. I see this is full of air. Is it air?

P: Its air

I: And what about here? What happened here?

P: All the air went to the balloon and the balloon get bigger.

I: Why did it all go to the balloon?

P: Because the balloon needs air to grow.

I: The balloon needs air to grow?

P: Yes

I: But why did the balloon leave the bottle to go to the balloon?

P: To make the balloon bigger

I: To make the balloon grow?

P: Okay. So lets move to the next question. Here I see you have air over there in the question number 4. You have air there and then when you pulled there is no air here in the second one. What happened?

P: No response)

I: Why?

P: (No response)

I: Hmn? There is the same air here. Why?

P: Because this one is not pulled so there is no air here but this one is pulled so the air goes outside.

I: So the air goes outside.

P: Yes

I: Okay. Lets go to the last question. Two drawing for you air? (Two circles)

P: There is not a lot of air.

I: There is not a lot of air in the first balloon?

P: Yes

I: And in the second balloon?

P: There is a lot of air.

I: There is a lot of air, okay. Lets see here. The first one there is not a lot of air also?

P: There is a little air.

I: There is a little air?

P: Yes

I: And here (in the second balloon)?

P: A lot of air.

I: A lot of air. Is it the same here also?

P: Yes sir.

I: And here?

P: A little air.

I: A little air. In the first balloon?

P: Okay, thank you very much.

Appendix XX: Final group interview school B inquiry class

I: Okay let's see. How did you. Why did you draw it like this?

P: It is air sir.

I: It is air?

P: Yes.

I: And I see there are circles. Why?

P: They are called micro…. Little ones.

I: Microscopic particles?

P: Yes.

I: Okay. So that's why you drew them like this?

P: Yes sir.

I: Okay and here I see you only drew at the bottom. Why? And it is shaded? Why?

P: It is air.

I: It is air?

P: Yes

I: So it means at the top here there is nothing?

P: no response.

I: Why? Is it sitting at the bottom?

P: No

I: No. Why? So why did you draw it only at the bottom?

P: No response

I: Hmn? You don't know? And here? I see you shaded all around.

P: Yes

I: What?

P: The bottle is full of air.

I: The bottle is full of air?

P: Yes.

I: And what about these things which are like snakes.

P: They are the particular things.

I: The particles?

P: Yes.

I: They are like snakes like this?

P: Yes.

I: Okay. And here you drew dots, dots dots. What does it mean?

P: Its air.

I: Its air?

P: Yes.

I: So these are what? What are they called? The dots?

P: (No response)

I: They are called the particles. Right.

P: Yes

I: And here I see you have dots and also things like snakes. What are they for?

P: They are air sir.

I: It is air?

P: Yes.

I: Okay. And on the second one you drew, it air again, with dots and those strings?

P: Yes

I: Okay

I: And here, my friend listen to me. Why do you have few dots here (in the ball with less air) than in the ball with much air?

P: This one has got a puncture and this one does not.

I: This one has a puncture? So what about the number of dots? Why did you draw a few dots?

P: It has less air.

I: It has less air? Some of the air left?

P: Yes

I: Okay. And here. I see you only shaded the bottom and there is nothing at the top. Why?

P: Because much air got out (in the punctured ball).

I: Much air got out?

P: Yes

I: So the much air got out only from the top?

P: Yes

I: And at the bottom its still there?

P: Yes

I: and at the much air it is full?

P: Yes

I: Here I see you only drew air at the centre. Why?

P: Because this one has a puncture.

I: Has a puncture?

P: Yes

I: So the air only come out at the sides it does not come out at the centre?

P: no response)

I: And here you only drew at the bottom. Why?

P: No response)

I: Does it not have air at the top here?

P: It does.

I: It has. My friend I see these ones now, the circles are now big?

P: Because the air fits in the shape. So the air took the shape of the ball.

I: Alright. And why are circles here small and here big?

P: No response)

I: At the one with less air the particles are small and at the on with much air the particles are big. Why is it big?

P: This one has got a little air.

I: Okay. Right lets go to the next page. Turn your paper to the next page. Right, I see there is no air here. Why?

P: The air is at the balloon.

I: The air is at the balloon?

P: Yes

I: Okay (Interruption). Now I see there was no air here, and now there is air there.

P: Sir the air in here is coming up into the balloon so the balloon is growing bigger.

I: But this is the same thing. Here I see there was no air here and now there is air. Where did it come from?

P: It come from the fire

I: It came from the fire? Okay. And here. It's the same there is are here and also there is air here? And what happened there. What is this at the bottom of the balloon?

P: Its air

I: What is it doing at the bottom of the balloon? Is it resting at the bottom? What happened? Why did you draw it like that?

P: (No response)

I: Okay. Lets see here. I see this is full of air. Is it air?

P: Its air

I: And what about here? What happened here?

P: All the air went to the balloon and the balloon get bigger.

I: Why did it all go to the balloon?

P: Because the balloon needs air to grow.

I: The balloon needs air to grow?

P: Yes

I: But why did the balloon leave the bottle to go to the balloon?

P: To make the balloon bigger

I: To make the balloon grow?

P: Okay. So lets move to the next question. Here I see you have air over there in the question number 4. You have air there and then when you pulled there is no air here in the second one. What happened?

P: No response)

I: Why?

P: (No response)

I: Hmn? There is the same air here. Why?

P: Because this one is not pulled so there is no air here but this one is pulled so the air goes outside.

I: So the air goes outside.

P: Yes

I: Okay. Lets go to the last question. Two drawing for you air? (Two circles)

P: There is not a lot of air.

I: There is not a lot of air in the first balloon?

P: Yes

I: And in the second balloon?

P: There is a lot of air.

I: There is a lot of air, okay. Lets see here. The first one there is not a lot of air also?

P: There is a little air.

I: There is a little air?

P: Yes

I: And here (in the second balloon)?

P: A lot of air.

I: A lot of air. Is it the same here also?

P: Yes sir.

I: And here?

P: A little air.

I: A little air. In the first balloon?

P: Okay, thank you very much.

Appendix XXI: Final group interview school A Lecture class

I: Okay now I am recording. I see you have drawn dots here, dots here, circles there, dots there, and circles and then some lines lines and dots. Why did you draw using dots?

P: Uncle I think they are … its not hot and its not closed. And they are all together.

I: They are all together?

P: Yes they are all together and they are many.

I: Tell me why did you use the dots in question number one there?

P: Because of, uncle, they are using the glasses which allow to see what is inside the glass. Eeh I don't know the glasses that allow you to see what is inside.

I: The magic glasses?

P: Yes the magic glasses

I: Okay

P: They were using it.

I: Alright, and you? Why did you draw using dots here?

P: I used dots because the balloon is not closed and there is not …. Uncle its gas.

I: Okay. And why did you draw lines here?

P: It looks like that because its full of air.

I: There is full air?

P: Yes

I: And my friend?

P: Uncles I draw that because its ..(Whispering)

I: Speak up.

P: mumbling)

I: Speak up.

P: Uncle its little …

I: Why did you draw it with circles?

P: uncle I draw it

I: Speak up.

P: Uncle I draw it circles because uncle it is not .. . it is not closed.

I: Okay. On the second question I see you have drawn there, there are few circles there?

P: Yes

I: Why? In the first one there is few circles?

P: Uncle there is few circles because it has a puncture uncle and the air is going out uncle and here uncle there is no a puncture so there is much air inside.

I: There is much air inside?

P: Yes uncle

I: So the circles stand for what?

P: Uncle its air.

I: Okay. Here I see here you have much. You have a lot of particles, dots in the first one and few dots in the second one?

P: Uncle its air that is going out and some of them is coming in and at the second one because the air is too much, they all spread.

I: They all spread?

P: Yes, but they are still inside. The air is the same but they are together inside the balloon and the ball is big.

I: Okay. And here I see that you have drawn in the second ball using dots and in the first one using circles. Why?

P: I used circles because in the first circle there is not much air. And then at the second one ther is much air.

I: So if there is not much air then you use circles?

P: Yes because they are .. because some are coming out.

I: Some are coming out?

P: Yes uncle.

I: Okay. Lets turn to the next question. Right. Here I see there are many circles here. What does it mean? Because there many circles here on the first one and few circles there on the second one. Why?

P: Because the fire is heating and so the air is getting in here.

I: Oh the air is going there?

P: Yes

I: Why is it going there?

P: Because the fire is heating

I: The fire is heating?

P: Yes

I: So it it running away from the fire?

P: Yes

I: Hmn?

P: Yes

I: So if it running away I don’t know. Why is it going there? Why is it nit staying there?

P: Eish, eish.

I: Like what this one is doing. Why is it not staying there? Is it because of the fire?

P: Yes

I: Okay. And here? I also see there is many dots there and then there are few dots there?

P: Yes uncle those is heated so they…

I: Its heated

P: Yes

I: So the number of dots becomes small?

P: Yes

I: How? Okay. Let's look at this one. I see you have many dots here, the first one and then this one? Are they spread out?

P: Yes they are spread out because this fire is so hot that they all feel heated.

I: Heated up?

P: Yes and then they spread out

I: And why does this one become big? The balloon?

P: The balloon becomes big because this fire is heating and these ones are are.. spreading…

I: Expanding?

P: Expanding and spreading into this one.

I: Okay. The next question, question number 4. I see here you have drawn the particles there and other this which are like strings strings?

P: Its air.

I: Its air? Why did you you draw it like that?

P: Uncle, if you look at it its like air but I make it a bit light.

I: you make a bit light?

P: Yes. So eish….. uncle….when they are all spreaded.

I: So they are pulled together?

P: Yes

I: Okay and there I see you have many particles in the first one and few in the second one. Why?

P: Uncle because uncle. Before taking out of air its full of air.

I: Okay the next question. I think it's the last one. The other side, the other side. Yes here I see you have just a line of particles there and then many particles in the second balloon. Why?

P: I used small air in the first balloon because it has a puncture and then I used a lot of particles in the second balloon because the balloon is pumping and its closed.

Okay. And here my friend I saw you used circles here a few of them. And here now you have lines lines. What does that mean?

P: Here there is.. there is much air in the balloon because pumped it and block it and tied it.

I: Alright. And here? This is full up to there and then on the neck of the balloon there is nothing. Why? Is there no air there?

P: There is air there, but its.. I couldn't show it because this air is comes out of the balloon. So it becomes smaller.

I: Okay. And here the balloon becomes what?

P; The balloon is bigger because its blown and tied.

I: Okay. Alright. Thank you very much.

Appendix XXII: Final group interview school A Inquiry class

I: Yes, you, why did you draw it like this with lines like that going up?

P: Because it it it comes of too much of gas I have drawn mine.

I: Okay, and you?

P: (pause) Because eeh, because you cannot you can look down from top and see air and there is lot of air inside.

I: Okay. And here why do you have dots and lines?

P: That's particles uncle and air.

I: Dots are the particles?

P: Yes

I: And the lines?

P: And the lines are the air.

I: Are the air?

P: Yes, are air.

I: Okay. And here I see you drew horizontal lines?

P: Yes because I made it because the blocked a long time ago. The air is flowing like this inside it.

I: The second one, I see you have drawn here sort of circles around in the balls. Why?

P: This one because here there is so much air and here there is less here because there is a puncture. So the air is going out here.

I: So the amount of circles show that the air is much?

P: Yes. Here it shows its less because its going out here from the puncture.

I: Okay. And also here I saw…

P: I drew like circles and some of the air is coming out at the puncture.

I: So what do the circles mean?

P: The circles mean the air and the air is coming out of the ball because there is a puncture.

I: Okay. I see you have lines going down in the first ball and and I don't know what they are doing in the second ball. What does it mean?

P: Up here they are air is out. The air is going out

I: So why did you not draw it like this in circles? Why?

P: (no response)

I: Why did you not draw it like this?

P: (No response)

I: Alright tell me you. I see you have 2 circles in the first one in the second one. Why?

P: The first is like a puncture and the gas inside is going out and less gas is left.

I: Okay lets go to the next question. Yes I see here. You said the lines mean air?

P: Yes.

I: Okay, you have drawn air in the first one, also here the air is in the second one and then the balloon is big but there is no air inside. Nothing in the balloon. What does it mean? Why is it big? But there is nothing?

P: Because, because the fire was heating the water and the water see that air coming up.

I: So is it the heat that made the balloon to be big?

P: Yes

I: The heat?

I: And here I see you have many dots in the first balloon and in the second picture the balloon is big. Why?

P: Here I draw here, this is the picture that make the balloon that big therefore makes it big.

I: Alright. Okay the next question. I see here circles, few circles in the first one and many circles in the second one. What does it mean?

P: Because here there are still air in here there still show there is no …. And here there is air to start here, when here one do it like this, it….. the air goes in here.

I: But why? Remember the other one you said the amount of circles, here, you said there are many circles because there is a lot of air. Here there are few circles because there is less air in the balls. And here there are a lot of circles in the second one and few circles in the first. So why do we have a lot of circles here?

P: Here I think there are becoming too many circles.

I: You made a mistake?

P: (Node)

I: Okay. Alright, lets go to the last question. Last question. Right, I see here you drew a few dots, a few dots here and some lines and many dots here and some lines, on the second balloon, why?

P: Because after the balloon has been fichered the air.

I: Has been punctured.

P: Has been punctured, the air is … there is …. The air is …. There is more light and the pump has to pump more ….

I: So why does the balloon become big?

P: Because there.. because they pumped it.

I: Because they pumped it?

P: Yes

I: And here, I see you have many dots here many many dots, and then you have two there.

P: There is two here because there is little gas because because there is a bit of gas. So there is little gas because there is very little air.

I: There is very little air here?

P: Yes

I: But why do we have so many dots if there is little air?

P: Because that .. particles and the gas, the gas don't get up to these spaces because these space means there is a lot of gas.

I: There is a lot where there is big space?

P: There is a lot of gas where there are fewer particles.

I: Where there are fewer particles?

P: Yes

I: Then there is a lot of gas?

P: Yah

I: Where is the gas, show me the gas here?

P: Here.

I: This dot is a what, is it a particle?

P: Yes

I: And that dot is a what, is it a particle?

P: Yes

I: And between them, what is between them?

P: Which ones?

I: Between the two dots? Between the two dots? What is it, what is there?

P: Aah (No response)

I: Is it the air? What is there?

P: Yah

I: Because you said here there is little air but there are many dots.

P: Yes

I: And then there is a lot of air and there are few dots. How does it happen?

P: Because when there is little particles means that there is lot of gas.

I: Okay, and you I see you have few lines there and many of them on the second balloon. Why?

P: The first one because they haven't filled it with air but there is still little air here.

I: Uh

P: This one they filled it with lot of air so I draw many bubbles (circles) to show that they filled it.

I: Alright, thank you, thank you so much.