Nigerian science teachers' beliefs about effective science teaching, their pedagogical content knowledge, and how these influence science teaching

Morris A. Benjamin

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NIgerian Science Teachers' Beliefs About Effective Science Teaching, Their Pedagogical Content Knowledge, and How These Influence Science Teaching

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B.Sc (Hons) PGDE, M.Sc, M.Ed

A thesis presented for the degree of Doctor of Philosophy

School of Education,
Faculty of Community Services, Education and Social Sciences,
Edith Cowan University,
Western Australia

June 2004
DECLARATION

I certify that this thesis does not, to the best of my knowledge and belief:

i. incorporate without acknowledgement any materials previously submitted for a degree or diploma in any institution of higher education;

ii. contain any materials previously published or written by another person except where due reference is made in the text; or

iii. contain any defamatory material

Ayiinde Benjamin

16/ November 2023
This study investigated Nigerian junior secondary science teachers’ beliefs about effective science teaching, their pedagogical content knowledge and how these influence their classroom teaching behaviour. The research is underpinned by a conceptual framework, which establishes a strong relationship between teachers’ beliefs about teaching, teachers’ pedagogical content knowledge and classroom teaching practices.

The study was carried out in two phases. The first phase involved a survey of all junior secondary science teachers (N=70) from the 30 secondary schools in two Local Education Districts of Lagos State, Nigeria. The second phase involved in-depth case studies of three science teachers who were purposively selected. The case study data were collected through interviews, classroom observation sessions and document analysis.

Findings from the study revealed that the teachers hold narrow, objectivist or realist views of the nature of science, and narrow and elitist views of the purpose of science teaching in schools. They also espoused beliefs consistent with knowledge transmission, teacher-centred, teacher-dominated classrooms in which students should play mainly passive roles of listening, observing the teacher and copying notes whilst under strict supervision of the teacher so as to maintain a quiet classroom for science teaching. Assessment practices are based on short paper and pencil periodic tests and terminal examinations, which are mainly for summative purposes.

The teachers’ classroom behaviour reflected accurate knowledge of science content and an understanding of the social and physical environment in which their students are learning. However, their teaching practices reflected pedagogical knowledge and skills, and knowledge of student learning derived from the traditional knowledge transmission pedagogy, which is not consistent with current understanding, and best practices in science teaching and learning. Their teacher-centred practices are consistent with their knowledge transmission beliefs and their pedagogical content knowledge in relation to pedagogical strategies and how students learn in science.
The study revealed that shortages of science textbooks, insufficient teaching facilities and large classes, limit teachers' effectiveness in science teaching. More contemporary approaches that actively engage students in learning and develop scientific literacy in the Nigerian context have been recommended. The implications of these findings for initial teacher education, professional development, science curriculum and science teaching have been outlined.
ACKNOWLEDGEMENTS

To God Almighty be the glory; in Him all things are made possible. This feat is the Lord’s doing; Glory be to His holly name.

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May God bless you all in Jesus name, Amen.
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CHAPTER 1: INTRODUCTION

Introduction

The focus of this study is to describe Nigerian science teachers' beliefs about effective science teaching and their pedagogical content knowledge, and the influence of these on classroom teaching behaviour. The intention is to understand why teachers teach the way they do and develop ways to help them adopt best practices that fit within their own framework. This Chapter presents the background to the study, the rationale and significance of the study, statement of the problem and the research questions.

Background to the Study

The Nigerian national policy on education (Federal Ministry of Education (FME), 1998) stipulates, among other things, that teaching of science subjects should be greatly emphasised and given priority in secondary schools. The policy document also emphasizes the need to provide qualified science teachers with intellectual ability for the school system so as to be able to meet the country's educational goals in the face of the fast growing world of science and technology. It is several years since the national policy came into being but the science educational goals are far from being achieved. Concerns have continued to be raised about the school system and particularly about the poor achievement of secondary school students in science (West African Examination Council, 1994). Studies have also questioned the quality of science teaching and learning in secondary schools (Ahove, 1997; Ajewole, 1990; Odubunmi, 1981). The situation calls for reform, and as science teachers are central to any educational reform, this study focuses on teachers' beliefs, pedagogical content knowledge (PCK), and teaching behaviour. Bybee (1993) is convinced that "the decisive component in reforming science education is the classroom teacher ... unless classroom teachers move beyond the status quo in science teaching, any reform will falter and eventually fail" (p. 144).

Cuban (1990) implies that reforms return again and again because policy makers ignore local factors including teachers' beliefs. If science education reformers desire to focus on the classroom teacher then teachers' perceptions of reform issues and their assumed
roles in the process should be taken into account. In reviewing science education research, Tobin, Tippin and Gallard (1994) summarised this point by stating:

"Future research should seek to enhance our understanding of the relationship between teacher beliefs and science education reform. Many of the reform attempts of the past have ignored the role of teacher beliefs in sustaining the status quo. The studies reviewed in this section suggest that teacher beliefs are a critical ingredient in the factors that determine what happen in the classrooms (p. 64)"

Science teachers and their beliefs may play a major role in science education reform since science teachers’ beliefs lead to actions, and these actions ultimately impact on students (Clark & Peterson, 1986). This critical relationship between the beliefs of teachers regarding implementation of science education reform efforts and instructional decisions has been recently documented (Czerniak, Lumpe, & Haney, 1999; Czerniak & Lumpe, 1996; Lumpe, Haney, & Czerniak, 1998). According to Bandura (1997) beliefs are thought to be the best indicators of the decisions people make throughout their lives. Beliefs have been defined in a variety of ways. Oliver and Koballa (1992) indicated that beliefs are oftentimes equated with knowledge, attitudes, and personal convictions, or reflect a person’s acceptance or rejection of a proposition. Yet beliefs are often confused with other related concepts such as attitudes, values, judgments, concepts and dispositions. Pajares (1992) explained that clusters of beliefs around a particular situation form attitudes, and attitudes become agendas that guide decisions and behaviour. In other words, people act on what they believe. The connections among clusters of beliefs create an individual’s values that guide one’s life and ultimately determine behaviour (Ajzen, 1985). Science teachers’ beliefs regarding teaching and learning will therefore influence their decisions about teaching and assessment strategies.

Concerns about poor science teaching and learning in our schools have raised questions about the quality of science teacher education. Teachers tend to teach the way they were taught (Kubota, 1997). In her description of the traditional method of teacher preparation in most colleges of education and universities, Kubota (1997) notes that science teachers being prepared in their science majors have listened attentively to lectures, gazed at materials presented on the overhead projectors or the chalkboards and
taken copious notes that are normally memorised for examinations. They have participated in laboratory science courses usually requiring them to conduct experiments that have pre-determined conclusions and are presented in a 'cookbook' fashion. It is no surprise then, that many of our science teachers tend to close their classroom doors to their colleagues, ignore the rich sources outside the classroom, focus on the textbook, and teach to the examination.

Research in cognitive psychology indicates that deep understanding of a topic requires not only individual construction and reflection, but also dialogue, discussion justification, and presentation of ideas with others (Roychoudhury, Roth & Ebbing, 1993; Schon, 1993). In addition, research also indicates that individuals construct their own theories of how the natural world works based on their prior experiences and knowledge and that these theories may be naïve and extremely difficult to change (Driver, Gueshe & Timberghien, 1985).

A number of reviews (Calderhead, 1996; Carlsen, 1987; Good, 1990) of science education have implied that improvement in teachers' content knowledge would lead to better teaching and hence better learning in science. Indeed, what actually constitutes the ‘science content’ required by teachers of science is rather more complex than that implied by a ‘background in science’. One aspect of this required background is some knowledge of the subject itself; the other is teacher's appropriate comprehension in the subject. Shulman (1987) aptly emphasised this in his statement: “indeed, we have reason to believe that teacher comprehension is more critical for the inquiry-oriented classroom than for its more didactic alternative” (p. 7).

Through the 1970s and the 1980s, the approach to the teaching of science in the UK and USA was largely process oriented (Kruger, Summers & Palacio, 1990). There was a focus on observation, hypothesising, recording and interpreting data, and application. The development of conceptual knowledge was masked by the emphasis on the development of skills and attitudes and by the rather simplistic view of the role of the teacher. Interactive teaching models that were proposed to take account of students' existing ideas (Biddulph & Osborne, 1984) led some to believe that the teacher needed only to be a ‘fellow traveller’ in the learning process. There has been a move to give greater emphasis to the teaching for conceptual understanding in science (Linn, 1992). As well as developing process skills and attitudes, students are expected to develop
knowledge and understanding of, and about science (Kruger et al., 1990). There is also a demand to ensure that the content and skills of science are set within relevant contexts (Fensham, 1985). These initiatives put additional demands on the teacher of science and highlight the limitations of the teacher who has only knowledge of the ‘facts’ and ideas of science and of the processes involved. Teachers of science need not only knowledge of the content and process of science, but also a view of the dynamic nature of science itself.

Teachers also require the ability to translate content knowledge into pedagogical content knowledge (Peterson & Treagust, 1992). Tamir (1991) maintains that such transformation is only useful when it becomes personal practical knowledge. Tamir argues that the problem a novice teacher faces is to absorb and internalise knowledge of the subject and of teaching in such a way that it becomes his or her personal practical knowledge which can be subsequently applied in teaching. Shulman (1986) suggests that the ability to transform subject knowledge into pedagogical subject matter knowledge is assisted by reflective practice. Indeed, Shulman introduced the concept of pedagogical content knowledge (PCK) in a paper in which he argued that research in teaching and teacher education has undeservedly ignored research questions dealing with the content of the lessons taught (Shulman, 1986). The concept of PCK refers to the teachers’ interpretations and transformations of subject matter knowledge in the context of facilitating student learning (van Driel, Valoop & De Vos, 1998).

Shulman (1986) introduced PCK as a specific category of knowledge, which, according to him, “goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching” (p. 9). The key elements in Shulman’s conception of PCK are knowledge of representations of the subject matter on the one hand and understanding of specific learning difficulties and student conception on the other. Obviously, these elements are intertwined. According to van Driel et al. (1998) “the more representations teachers have at their disposal and the better they recognise learning difficulties, the more effectively they can deploy their pedagogical content knowledge” (p. 5).

In a later article, Shulman included pedagogical content knowledge in what he called “the knowledge base for teaching” (p. 9). This knowledge base consists of seven categories, three of which are content related (i.e., content knowledge, pedagogical content knowledge (PCK) and curriculum knowledge). The other four categories refer
to general pedagogy, learners and their characteristics, educational contexts and educational purposes (Shulman, 1987). Thus Shulman's knowledge base encompasses every category of knowledge, which may be relevant for teaching. This can therefore be explained as follows. PCK implies an integration or transformation of subject matter knowledge and knowledge of general pedagogy so that it can be used effectively and flexibly in communication between the teacher and learners.

While elaborating on Shulman's work, other scholars have adopted the two elements of PCK mentioned above i.e. knowledge of comprehensible representation of subject matter and understanding of content related learning difficulties. Moreover, each of them has extended the concept by including in PCK some other categories of knowledge distinct in Shulman's knowledge base for teaching. For example, Grossman (1990) perceived PCK as consisting of strategies and representations for teaching particular topics, and knowledge of students' understanding, conceptions and misconceptions of these topics. In Grossman's model of teacher knowledge, PCK is at the heart, surrounded by three related categories; namely, knowledge of subject matter, general pedagogical knowledge, and contextual knowledge. Grossman identified the following sources from which pedagogical content knowledge is generated and developed: observation of classes, disciplinary education which may lead to personal preferences for specific purposes or topics, specific courses during teacher education of which the impact is normally unknown, and classroom experience.

Science Teaching in Nigerian Secondary Schools

All the 42 universities and the 58 colleges of education in Nigeria are involved in preparing teachers for the school system. The colleges of education prepare teachers for the primary and junior secondary schools while the universities prepare teachers for the senior secondary schools. Even though the enrolment of students in the colleges of education has increased from 84,742 in 1991/92 to 105,817 in 1996/97 (FME, 2000), it is far from satisfying the demand for quality teachers. The school system is faced with the problems of inadequate supply and quality of science teachers and a high dropout rate of students. The rationale, context and expectations in science teaching and learning in the Nigerian education system are discussed in this section.

Issues of workforce planning, economic growth, and social reforms among others led to the inauguration of the 1969 education conference in Nigeria. During this conference it
was noted that the school curriculum was not relevant in content and pedagogical approach especially in the area of science (Fafunwa, 1974). The 6-3-3-4 system of education, which translated into six years of primary, three years of junior secondary, three years of senior secondary and four years of tertiary education, was the outcome of the conference and it specifically stipulated the introduction of science at the primary school level, Integrated Science at the junior secondary level and Physics, Chemistry, and Biology at the senior secondary level (Federal Republic of Nigeria (FRN), 1982). This, no doubt, was in response to the worldwide call for greater attention towards the improvement of scientific and technological literacy. The expected effect of this was to produce citizens who are better empowered to lead productive lives and to enjoy the best possible quality of lives having acquired at least a basic understanding of science.

In 1993, a UNESCO report argued that scientific and technological literacy is essential for achieving responsible and sustainable development (UNESCO, 1993). As already pointed out, the Nigerian educational policy document stipulated that science should be taught at junior secondary schools in the ‘integrated form’ which was based on the principle of the ‘broad-field curriculum design’ that implies that the different forms of knowledge are not entirely distinct. The integrated principles are intended to produce a science course, which:

- is relevant to the child’s need and experience;
- stresses the fundamental unity of science;
- lays adequate foundations for subsequent special studies; and
- adds a cultural dimension to science education.

(FRN, 1982)

Integrated Science teaching is recognised as being fundamental to the strengthening of scientific and technological understanding at higher levels of education. Odubummi (1981) observed that exposure to the core curriculum of Integrated Science would provide enough scientific experience in understanding basic concepts in biology, chemistry, and physics to prepare students for the study of science in the senior secondary years. Similarly, Adeyegbe (1993) noted that many students who enrol for senior secondary school science subjects do so only on the strength of their performance in the junior secondary school Integrated Science examination results. Teaching of Integrated Science in the junior secondary years is therefore fundamental to the effective participation of students in sciences at higher levels of education.
Consistent with the national education policy document (FRN, 1982), science is made compulsory at the junior secondary school level. At the senior secondary school level, science is taught as core learning areas: Chemistry, Biology, Physics, and Agricultural Science. In order to ensure that every child who completes secondary school education is scientifically literate, it is compulsory that every student completes, at least, one science subject and mathematics in each of the three years of senior secondary school education.

A national primary science curriculum document (FME, 1981) guides the teaching of science in both private and public primary schools. A national curriculum also exists for junior secondary Integrated Science, which is used in all the States of the Federation in both public and private schools. The same also applies to each of the core science subject areas taught in the senior secondary schools. The Nigerian secondary science curriculum document (Federal Ministry of Education (FME), 1985) has been described as student-centred and activity-based and recommends that science be taught by a guided discovery approach. An assessment practice in science teaching at both the primary and the secondary levels is based on continuous assessment tests and quizzes. Assessment of student outcomes in secondary science is usually formal, typically norm-referenced, summative and is usually focused on content.

Despite the fact that the National policy on education stipulates that science and mathematics be given priority in secondary schools, the level of student participation in the sciences remains quite low. An expected return on government investment on education, on the other hand, has not been encouraging. The responsibility for science teacher education rests with both the Federal and State Governments in Nigeria.

Rationale and Significance of the Study

The Nigeria national policy on education (FME, 1998) stipulates, among other things, that science teaching and learning be given priority at all levels of the education system. Based on the policy document, the junior secondary school curriculum has been designed to provide academic, vocational and pre-vocational background for students. A student completing junior secondary schooling is expected to either proceed to the senior secondary school, vocational school, or enter the world of work (Ojeme, 1988). The senior secondary school curriculum is a continuation of the junior secondary
curriculum. It is more comprehensive, and has the following general aims for science education:
(a) To equip students to live effectively in our modern age of science and technology; and,
(b) Produce a generation of people who can think reflectively for themselves and respect those values which we live for.

Therefore, the Nigerian system of education is focused on developing sound and effective citizens as well as equipping them to contribute to building a technologically and industrially buoyant nation. Governments of the federation have realised that without science education as a tool, the national aims and objectives would be difficult to achieve and subsequently they have continued to direct the bulk of the government resources to science and technology education.

Considering the financial, material, and human investments in education in Nigeria since the inception of the National policy on education as well as the high priority placed on the study of the sciences, the returns are not commensurate with the level of investment. This can be seen in the poor level of students' performances in science subjects in the West African Examination Council (WAEC, 1994) and Joint Admission and Matriculation Board (JAMB, 1995) reports (Obemeata, 1995; Onwuakpa, 1997; Uwadiae, 1997).

Moreover, teachers are an integral part of any educational policy. This is because no matter how relevant a curriculum document can be, its implementation relies heavily on the teachers if it is to yield any successful results (Nwosu, 1991). It is right to assume that the effective implementation of any curriculum and the attainment of their lofty objectives rest on the quality of teachers implementing them (Adeyegbe, 1993). This therefore, calls for teachers to be knowledgeable in their various disciplines. Observations have shown that many of the teachers in the school system are not professionally qualified and are in short supply. Supporting this view, Balogun (1991), in her study revealed that 62.5% of secondary science teachers possess a Bachelor of Science degree in various subject areas while about 25% have a Nigeria Certificate of Education (NCE). There may be as many as one third of secondary science teachers who do not have either a Bachelor of Science education degree or an NCE. This is likely to contribute to students' poor achievement in science. Efforts have continued to
be made to prepare more and better science teachers both by the universities and the colleges of education. These efforts are not perceived to have positively influenced students' achievement in science.

It is in the light of the above, that the Researcher is motivated to undertake this study with the central aim of investigating the beliefs of science teachers about teaching effectiveness in science and their pedagogical content knowledge, and how these influence their classroom teaching practice. Furthermore, the desire to undertake the study also arises from the Researcher's curiosity and involvement in science teaching and teacher education at the college of education in Lagos State of Nigeria. It is anticipated that the findings from this study will help teachers and teacher educators understand why Nigerian junior secondary science teachers teach the way they do, and hence inform teacher education and curriculum reforms in science education.

**Statement of the Problem**

The second Nigeria National Development Plan recognised education as a tool for achieving national aims and objectives (Federal Republic of Nigeria (FRN), 1982, and hence identified four national educational aims and objectives. The objectives, among others, include "the acquisition of appropriate skills, abilities and competencies both mental and physical as equipment for the individual to live in and contribute to the development of his society" (FRN, 1982, p. 6). Education in science and technology is the most appropriate vehicle for the transformation of the individual and society (Jegede, Lagoke, Okebukola & Nzewi, 1996; Okeke, 1996). This can be achieved if effective science teaching is achieved in the secondary schools. However, it is now obvious that using education as a tool for realising national objectives might remain a dream for a long time, based on current low standards and student achievement particularly in science education in our secondary schools (Obemeata, 1995; Onwuakpa, 1997; Uwadiae, 1997). Considering the financial, material and human investments in education in Nigeria since the inception of the National Policy on Education, as well as the high priority placed on the study of science, the returns are far from being commensurate with the level of investment. This can be seen in the poor level of student performance in science subjects as recorded by WAEC (1994) and JAMB (1995) reports.
Maduabum (1995) reported the results of the Third International Mathematics and Science Study (TIMSS) (OECD/PISA, 1999; STAN, 1992), in which different countries participated. Nigerian pupils ranked last in primary science and second to last in secondary science. The report is quite disheartening and suggests that Nigerian secondary school science does not meet international benchmarks of student achievement. Earlier studies (Nwosu, 1991; Okebukola, 1985) have also indicated poor quality teaching of science subjects, including Integrated Science, and poor performance of students in the science subjects. There is therefore, the need for reforms in order to bring about effective teaching and learning of science.

**Purpose and Research Questions**

Teachers are believed to be central to any educational reform. Adequate knowledge of teachers' beliefs, PCK and teaching practices is necessary if teachers are to be helped to adopt best pedagogical practice appropriate for their Nigerian context. This study focuses on junior secondary science teachers' beliefs about teaching effectiveness in science, their pedagogical content knowledge, and how these influence their classroom behaviour.

The following research questions have been formulated to provide a focus for the investigation:

1. What are Nigerian junior secondary school science teachers' beliefs about effective science teaching?
2. What are the characteristics of the science teachers' teaching behaviour?
3. What aspects of teachers' pedagogical content knowledge are manifest in the teachers' classroom behaviour?
4. What factors inhibit science teachers from achieving teaching effectiveness in science?
5. To what extent do the teachers' classroom teaching practices appear to be influenced by their beliefs about effective science teaching and by their pedagogical content knowledge?
CHAPTER 2: LITERATURE REVIEW

Introduction

This literature review is presented in four parts. The first section discusses science education in Africa and the state of secondary science education in Nigeria. The second section focuses on issues relating to effective science teaching and learning and specifically addresses the nature of science and science teaching, the need for scientific literacy, science teaching through inquiry, constructivist teaching and learning, effective teaching behaviours, student learning behaviour, and assessment as an integral part of science teaching and learning. The third section considers issues relating to teachers’ beliefs and their influence on science teaching and learning. The last section discusses science teachers’ pedagogical content knowledge and the relationship between pedagogical content knowledge and teaching behaviour.

Science Education in Africa

Science education in Africa has been greatly influenced by the educational systems in the United States of America and the United Kingdom (Ogunniyi, 1986). Before the early 1960s, the science curriculum in most African countries was geared toward the fulfilment of overseas examination requirements, namely the Cambridge School Certificate Examinations, the London General Certificate of Education for the Anglophone countries and the Baccalaureate Parts one and two for Franco-phone countries. Uptil now, some African countries including Lesotho, Swaziland and Botswana still gear their science curriculum towards the Cambridge school certificate examinations. Science education objectives commonly found in curriculum documents of practically all independent African States, starting from the early 1960s, include (1) development of the spirit of inquiry; (2) understanding of the nature of science; (3) the teaching of problem solving using scientific techniques; (4) acquiring the culture of scientific literacy; (5) development of manipulative skills and scientific attitudes; (6) understanding the interaction between science and society; and (7) transformation of the environment (Ogunniyi, 1986).

At the lower secondary school level, subjects from the fields of science and technology have often been integrated within the curriculum. Haggis (1980) advanced three
reasons for this: (1) the interdisciplinary nature of science; (2) the multifaceted nature of education; and, (3) socio-political concern about science teaching and learning. Other reasons that have been given include the fact that primary science was taught as an integrated curriculum rather than as different science disciplines, and the fact that this stage marks the end of science for a large proportion of students (Cole, 1975). Whether or not the content of the Integrated Science curriculum depicts the unity of science adequately has been a matter of great concern (Yoloye, & Bajah, 1981).

At the upper secondary school level, there has been a gradual shift in emphasis from the mere acquisition of scientific facts and principles to inquiry and problem-solving activities. The main constraint, however, has been the strong influence of external examinations on the whole educational system. Within the past two decades the West African Examination Council and the East African Examination Council have completely taken over the conduct of examinations from the Cambridge Overseas Syndicate.

Greater emphasis was placed on rural transformation through the teaching of agricultural science and the inclusion of technological topics in primary and lower secondary school science curricula (Ogunniyi, 1979). The theme of the first African International Conference for Science Education (FSE), which took place in Harare in 1982, was "How Relevant is Science Education to the School Dropout." Delegates at the conference anticipated that by 1990 most African States would have achieved a reasonable level of scientific and technological literacy. The experience of the past two decades, however, has brought about a strong awareness throughout Africa that the present form of science being taught in the schools does not prepare pupils to function well in a society undergoing transition from a rural to a modern economy (Balogun, 1975). This concern was enunciated in the FSE conference resolutions (Ogunniyi, 1986):

We are aware of the goal of education to produce human beings that are self-reliant. We are aware of the failure in many ways of our current science education programs to prepare students, be it at the secondary school level or at the primary school level for useful living. We observe that most African governments have in no way supported and sustained
action programs to make science education functional with a view to replacing or complementing academic preparation... (p. 118)

After gaining their political independence, many African countries embraced reforms in education influenced by (Jegede, 1988):

1. the apparent dysfunctionality of the inherited educational programs that were largely imported through colonialism;
2. the experience some members of the African scientific and science education communities gained by their sojourn abroad in search of further education; and
3. the prevailing climate of political independence which, by implication, extended to other areas of the aspirations of the newly independent countries.

While several countries took part in the development and implementation of the African Primary Science Program (APSP), some embarked on developing new programs (e.g. the Bendel State Primary Science (BSPS), Primary Education Improvement Program (PEIP) and the Nigerian Integrated Science Project in Nigeria) and others adopted wholesale some foreign programs (e.g. Uganda, Kenya and Lesotho imported the Nuffield materials). Abimbola (1978) asserts that those major post-independent steps in science education in Africa were wrongly taken for two major reasons. First, the adaptation or adoption of other programs was not preceded by any prior determination of what the new science education programs were expected to achieve for the students or the countries. Second, only minimal changes have been noticed in the learners' level of achievement, even though, as found out by Taiwo (1975) and Jegede (1987), the new programs offered a more progressive method for science teaching. Iroegbu (1987) explains that most African countries held positive views of their various programs because of their erroneous beliefs that the heavy loading of the curriculum with facts and information is essential for the much-needed technological development in Africa. In most of the countries little attention is focused on the philosophical bases of science education (Glaser, 1991). The main problems with reforming science education in Africa can be summarised as follows:

1. Science education reforms in pre and post independent Africa have been diffuse and cosmetic, not having a well defined focus and could not be justified from any conceivable philosophical stand-point (Glaser, 1991; Jegede & Okebukola, 1990).
2. The importation, adoption or adaptation of science curriculum materials into African classrooms fell short of the minimum expectations. On the one hand, they were not
grafted on any philosophical foundations, while on another it was not realised that these new curricula did not achieve some of the targets envisaged in their countries of origin (Hodson, 1988).

3. Science teaching in Africa has not identified with context-specific issues of the countries of the continent (Gallagher & Dawson, 1984; Jegede, 1988).

4. It is obvious that the socio-cultural backgrounds of learners of science in Africa have been ignored and not taken into consideration in the quest for an appropriate curriculum that can bring about scientific literacy in Africa (Ogbu, 1992).

Science has become an international currency for national and global technological development. Any nation that disregards this role of science does so at its own peril (Ogunniyi, 1997). Indeed, the level of science and technology development in a country or region serves as an indicator of the general standard of living (Balogun, 1997; UNESCO, 1993). An encouraging start was made in 1992 with the establishment of the project, Development of Science Culture in Africa (DESCA) by the African Academy of Science. Issues considered by the project include the effect science and technology has on traditional cultures (Abdulahi, 1982; African Academy of Science, 1991). Various other projects such as Science in Ghanaian Society Project (SGSP), Environmental Awareness and Science Education Project (EASEP) in Nigeria, the Zimbabwe Science Project (Zim-Sci), and the Kenyan Literacy Program (KLP), are all committed to having a broad-based scientific culture in Africa.

Furthermore, other regional programs e.g. the Science Education Program of Africa (SEPA); and within individual countries, such as the Nigeria Integrated Science Project (NISP), are positive indications that Africa is prepared to move with the current global trend in science education to achieve scientific literacy for its own development. Despite the efforts, not much has been achieved in terms of achieving scientific literacy in Africa because of the inability to effectively teach science in the schools. The science curriculum in many of the countries has been described as basically irrelevant (Balogun, 1975, 1997); most schools lack laboratories and facilities and adequately qualified science teachers (Bajah, 1997), and instruction is largely didactic (Ivowi, 1995). Because of the focus of this study, the state of secondary science education in Nigeria is further discussed in the next section.
Secondary Science Education in Nigeria

The state of secondary science teaching and learning in Nigeria has been the subject of recent research. Research has examined issues of classroom and laboratory facilities, curriculum and curriculum delivery, as well as student and teacher morale. Regarding classroom and laboratory facilities, the World Bank evaluation of the secondary education sector, conducted in Nigeria in 1991, revealed that laboratories in all of the Colleges owned by the federal government were adequate in terms of size, number and type, and in good state of repair (Okebukola, 1995; UNICEF, 1992). Most laboratories in non-federal schools were found inadequate in number, type, and size. Maintenance was reported to be generally poor. Only 15% of science teachers reported that safety measures in the state school laboratories were adequate, with the least adequate provisions in Physics, Chemistry, and Integrated Science (UNICEF, 1992). Gas supply is a problem especially in rural secondary schools.

Reports by Okebukola (1995) and Bajah (1997) indicate that the classrooms and laboratories where teaching and learning of science are conducted in Nigeria, are grossly inadequate in terms of furniture, fittings and equipment. In a study by Fraser, Jegede and Okebukola (1992) a significant gap was found to exist between Nigeria students' preferred and actual science laboratory environments. Although students preferred their science laboratory environment to be investigatory, open and with materials to work as 'scientists' do; the study shows the actual laboratory environment to be confirmatory, closed and not having enough materials to work with.

The junior secondary science curriculum is intended to be characterised by the spiral approach to the teaching of concepts, using the guided discovery approach in teaching as a way of ensuring that learning as an activity takes place during exploration, experimentation and discussions. Content is arranged in a logical, developmental and sequential order with an array of identified performance objectives for each topic of the curriculum (Ivowi, 1995).

Ikeobi (1995) observed that while the science curriculum in Nigeria is elegant in terms of intended goals, the achieved curriculum is hampered by teaching techniques that are not aligned with the spirit of inquiry in science. He asserts that in over 70% of the
science lessons studied the main teaching strategy is the lecture. Students in the science stream in secondary schools, in spite of the limitations in terms of facilities, are highly motivated to study science (Ikeobi, 1995). The findings of the study by Okebukola (1995) in Biology also confirm the positive motivation of the students. In contrast, science teachers have low levels of motivation because of some stressful factors in the school environment (Jegede & Okebukola, 1993). Jegede and Okebukola (1993) assert that Nigerian science teachers generally perceive administrative conditions, class and laboratory facilities, and students' attitudes towards science, to be 'harsh' and not supportive of the delivery of good quality science teaching.

Science and mathematics are allotted about 25% of curriculum time (divided equally between the two subjects) and this is regarded as being insufficient for students and teachers to cover the two syllabuses (Okebukola, 1997). Science teachers prepare lesson plans, but these are essentially lists of facts to be disseminated (Ivowi, 1995). Science teaching is virtually alienated from the environment and usually examination focussed. Classes are marked by lack of students’ involvement in the classroom teaching and learning processes, and inadequate instructional materials (Ivowi 1995; Ikeobi, 1995).

A survey of the causes of students’ under-achievement in science conducted by the Science Teachers Association of Nigeria (STAN), (1992) identifies several causes. These include gross under-funding, inadequate reward for teaching, overloaded syllabus, low morale, teachers’ inadequate knowledge of subject matter, lack of adequate pedagogical skills, shortage of qualified science teachers, poor attitude of students towards science, overcrowded classrooms, inadequacy of facilities, negative influence of cultural beliefs, and lack of provision of educational needs by parents among other things. Reports by Ikeobi (1995) and Ivowi (1995) confirm that these problems still lingered in the mid ‘90s.

The degree of relevance of the science being taught in schools has been questioned (Cobern, 1996; Ogunniyi, 1986). Cobern (1996) asserts that individuals and cultures have their views of the world, which form their foundation of thought, emotion and behaviour. The African child may have peculiar views of the world, which deviates significantly from the way science is presented to him or her. These views notwithstanding, there are no records indicating that science education derived from the
Western world constitutes any educational problems in the Nigerian context. It is a fact that most of the curricular materials including texts in use to date are derived from the Western education and the majority of the science teachers have acquired a Western education. Moreover, educational reform efforts in this part of the world have always been appraised in relation to the ideals in the western world and are geared towards achieving such ideals. This author believes that the western ideals of effective science teaching are achievable within the constraints and socio-cultural context of the Nigerian schools. Cultural issues are regarded as important in this investigation only to the extent that they are regarded as part of the contextual factors that may influence science teachers' beliefs and classroom practice. Science teachers that possess adequate knowledge of what science is and what it does should also have the capacity to make it relevant in any context.

The state of science education in Nigerian secondary schools reviewed in this section indicates that effective science teaching and learning is hampered not only by inadequate infrastructures and facilities but also by quality of teaching. Some questions are also being raised about the relevance of the type of science taught in the schools.

The Nature of Science

It is important that science teachers recognise the need to portray science as an attempt being made by a group of people to understand how the world around us works (Dawson, 1997). As students grow older they come to understand the world better and better, and it has been claimed (Cobern, 1996) that this results from learning processes, which closely resemble those used in science. Cobern (1996) asserts that scientific literacy is achieved only when the teacher is able to bring about a change in students' original ideas about the world and they begin to see the world scientifically. Students need to understand that science tries to develop better explanations for natural phenomena and does this by continually identifying problems and seeking provisional answers to them (Dawson, 1997).

Knowledge of the nature of science is fundamental to the achievement of scientific literacy. Indeed, students' understanding of the nature of science is currently being emphasised as an important educational objective worldwide (Lederman, 1992). The United States' benchmarks for science literacy (American Association for the
Advancement of Science (AAAS), 1993) and the National Science Education Standards (National Research Council (NRC), 1996) have a strong emphasis on the nature of science as a common theme. Lederman (1992) points out that the strong emphasis on the nature of science by the educational reform documents stems from the fact that students' understanding of the nature of science has been identified as an educational outcome in the United States since 1907. Such understanding is considered to be a significant aspect of scientific literacy (Lederman, 1992).

In his study of pre-service teachers' knowledge of the nature of science, Lederman (1992) found that students exhibited change in understanding only in the areas in which explicit instruction on the nature of science was provided. Griffiths and Barham (1993) found that few upper secondary Australian high school students understand what science is trying to do, or how it proceeds. According to their finding, a good number perceive science as lacking a human dimension and not being creative, and believe that neither scientific facts nor scientific laws can be changed. Quite simply, the assumption that students are likely to learn about the nature of science through implicit instruction (i.e. performance of scientific inquiry with no reflection on the nature of the activity) should be called into question. Providing students with experiences in scientific inquiry is certainly a start, but students need to have the nature of science made explicit through discussions and reflections about the nature of inquiry.

The significant misunderstandings that both students and teachers hold regarding the nature of science are particularly damaging to general scientific literacy because they affect students' attitudes towards science and science classes, and that clearly has an impact on students' learning and the selection of further science classes. For example, Tobias (1990) interviewed a number of science students and reported that they had become disenchanted with science classes and had chosen different majors partly because they did not understand the nature of science and what it is all about. Teachers had ignored the historical, philosophical and sociological foundations of science. According to McComas, Clough and Almazroa (1998), a better understanding of the nature of science, scientists and the scientific community will enhance:

- an understanding of science and it's limitations;
- interest in science and science classes;
- social decision making;
- instructional delivery; and
• the learning of science content (p. 2).

Thus, in the bid to achieve scientific literacy, science teachers, through explicit discussions and processes of inquiry, should help students to understand that the scientific way of knowing differs markedly from that used everyday (Dawson, 1997). A universal, ahistoric scientific method does not exist and indeed science is not completely objective or democratic. Science teachers should know that there is no hierarchical relationship between theory, law and hypothesis. While scientific laws are generalisations or universal relationships concerning the way that some aspect of the natural world behaves under specific conditions, scientific theories predict and explain the laws and provide the conceptual frameworks for further research (Kuhn, 1970). Ideas that are speculative, gaining support, but are not yet established are often referred to as hypothesis; it can also mean a guess or a well-informed speculation (Clough, 2000). Science teachers need to help students to understand that science is bounded. It deals with the natural world and consequently, its explanations are couched in natural expressions with no recourse to the supernatural. That anomaly in scientific findings do not always result in rejection of ideas in science and more importantly that science involves a unique way of thinking that significantly departs from everyday thinking (Cromer, 1993; Matthews, 1994; Pinker, 1997; Shamos, 1995).

To be effective in teaching the nature of science, teachers must believe that such knowledge is both important and crucial to achieving scientific literacy and then design instruction deliberately to achieve the goal. The United States National Science Education Standards (NRC, 1996) identify the study of issues relating science, technology and societal needs and values in a developmentally appropriate way as an essential part of any efforts to teach the nature of science to students.

The literature reviewed in this section indicates that knowledge of the nature of science is an important aspect of scientific literacy. The next section focuses on scientific literacy as a general goal of science education.

Scientific Literacy

The sustained prosperity of a nation depends in part upon the level and quality of its education system. Science education empowers individuals and maximises national
intellectual resources in order to sustain social and economic progress for the benefit of all (Zymelman, 1990). Nations of the world are becoming increasingly aware of the need to develop the intellectual capacity of their citizens, especially in science and technology. Science educators and major science education organisations are also increasingly advocating the preparation of scientifically literate individuals.

In 1989, the American Association for the Advancement of Science (AAAS), through its Project 2061, published *Science for All Americans*, defining scientific literacy as a general goal of science education. A subsequent project established the *National Science Education Standards* (NRC, 1996) for American school system, which are designed to guide the nation towards a scientifically literate society. The *Standards* describe a vision of the scientifically literate person and present criteria for science education that will allow the vision to become a reality. According to the AAAS document (1989), "science understanding and ability will enhance the capability of all students to hold meaningful and productive jobs in the future. The business community needs entry-level workers with the ability to learn, reason, think creatively, make decisions, and solve problems" (p. 13). Among the goals for school science, which underlie the *National Science Education Standards*, are to educate students so that they can:

- experience the richness and excitement of knowing about and understanding the natural world;
- use appropriate scientific processes and principles in making personal decisions;
- engage intelligently in public discourse and debate about matters of scientific and technological concern; and,
- increase their economic productivity through the use of the knowledge, understanding, and skills of scientific literacy in their careers. (AAAS, 1993, p. 13).

The New York State Department of Education, in responding to the call for new educational goals and standards in science teaching at high school level, has re-written its curriculum to reflect a more inquiry based approach to learning (NRC, 1996; National Science Teacher Association (NSTA), 1998). This shift in policy reflects the belief that scientific literacy encompasses mathematics and technology as well as natural and social sciences, has numerous aspects or facets (NSTA, 1998). The many facets, as defined by the NSTA, include:
being familiar with the natural world and respecting its unity; being aware of some important ways in which mathematics, technology and the sciences depend upon one another; understanding some of the key concepts and principles of science; having a capacity for scientific ways of thinking; knowing that science, mathematics and technology are human enterprises and knowing what that implies about their strengths and limitations; and being able to use scientific knowledge and ways of thinking for personal and social purposes (Rutherford & Ahlgren, 1990, p. 15).

The Michigan Department of Education in its vision for science education describes science as 'the basis for the design of technologies that solve real-world problems' (Michigan Department of Education, 1991). The document further states: "not all students will become scientists or engineers. But science and technology occupy ever-expanding places in our daily lives. As citizens, we are often asked to make decisions about social issues that involve science and technology. As workers, we have occupations that increasingly involve science and technology and in this 21st century as adults, we need to be comfortable and competent in a complex scientific and technological world" (p. 2).

The recently concluded two-year project in the United Kingdom, funded by the Nuffield Foundation, explored ways in which a new science curriculum might be constructed as a result of dissatisfaction with the current one (Millar & Osborne, 1998). The project was to pay particular attention to the aims and goals of education in the United Kingdom and Wales, and among other things was to consider four main questions: What are the successes and failures of science education to date? What science education do young people need today? What might be the form and structure of a suitable model for a science curriculum for all young people? What problems and issues would be raised by the implementation of such curriculum and how might these be addressed? Reiss, Millar and Osborne (1999) commenting on the curriculum and science educational goals in England and Wales state:

Education, at the end of the 20th century, no longer prepares individuals for secure, lifelong employment in local industry or services. Our view is that the form of science Education currently offered to young people in England and Wales is out modelled, and is too strongly influenced by the
need to be a preparatory education for the small proportion who will become our future scientists...there are further problems with the curriculum with too much emphasis on content, which is often taught in isolation from the kinds of context which could provide relevance and meaning. We lack a well-articulated set of aims and an agreed model for the development of pupil's scientific capability over the 5-16 age range and beyond (p. 68).

Millar (1996) had recognised the problem of the dual purpose facing the science curricula in the U.K. The purpose of providing the first stage of training in science for the minority of students who go on to science related careers; and, to provide basic scientific literacy for the majority who don't. Millar observed that these goals could hardly be achieved with any one curriculum. In the light of the perceived strength and weaknesses of the current state of science education in the U.K, the Nuffield Foundation report: Beyond 2000: Science Education for the Future, (Millar & Osborne, 1998) made recommendations, which include:

- that science curriculum for students from 5 to 16 years should be seen primarily as a course to enhance the general goal of 'scientific literacy'.
- that at Key Stage 4, the structure of the science curriculum needs to differentiate more explicitly between those elements designed to enhance 'scientific literacy' and those representing the early stages of specialist training in science, so that the requirements for the latter do not come to distort the former,
- that work should be undertaken to explore how aspects of technology and applications of science currently omitted could be incorporated within a science curriculum designed to enhance 'scientific literacy' and so on (p. 68).

The Western Australian Curriculum Framework (Curriculum Council, 1997), defining the rationale for scientific literacy states:

Science is part of human experience and has relevance for everyone. All people need a knowledge of science so that they can understand the world in which they live, value the systems and processes that support life on our planet, and take a responsible role in using science and its
applications in their daily lives...The applications of science transform large parts of social, political and economic life” (p. 211).

It is apparent that many science educators support Bybee’s (1997) description of scientific literacy as being the overall aim or general purpose of science education. The term scientific literacy expresses major purposes of science education, which is, the achievement of society’s aspirations and development of individual’s understanding about science and technology (Bybee, 1997).

The National Science Education Standards (NSES) (NRC, 1996) defines scientific literacy as the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs and economic productivity. The content standards of the NSES explain:

Scientific literacy means that a person can ask, find or determine answers to questions derived from curiosity about everyday experiences. It means that he/she has the ability to describe, explain and predict natural phenomena. Scientific literacy entails being able to read with understanding articles about science in the popular press and to engage in social conversations about the validity of the conclusions. Scientific literacy implies that a person can identify scientific issues underlying national and local decision and express positions that are scientifically and technologically informed (p. 22).

Showalter (1974) outlines some perspective of scientific literacy:

The scientifically literate person understands the nature of scientific knowledge, accurately applies appropriate science concepts, principles, laws and theories, in interacting with the universe. He uses processes of science in solving problems, making decisions, and for further understanding of the universe... (p. 20).

Bybee (1993) proposes that general education is the dominant perspective suggested by the term scientific literacy. He points out that the development of science education programs should begin with purposes aligned with general education. The intent of a
general education approach to science curriculum is to introduce those experiences, relationships, and ethical matters that are common to all members of a society at a particular historical moment. Showalter (1974) states that scientific literacy should be viewed as a continuum along which an individual can make progress. In agreement with Showalter's view, Bybee (1997) observed that scientific literacy is best defined as a 'continuum of understanding' and that the term should be represented as a continuum along which one develops for a lifetime.

In their review on science education in Australian schools, Goodrum, Hackling and Rennie (2001) define scientific literacy as:

> the capacity of persons to be interested in and understand the world around them, to engage in the discourses of and about science, to be sceptical and questioning of claims made by others about scientific matters, to be able to identify questions and draw evidence-based conclusions and to make informed decisions about the environment and their own health and well being” (p. 15).

The OECD Program for International Student Assessment (OECD/PISA), in its operational definition of scientific literacy states:

> Scientific literacy is the capacity to use scientific knowledge; to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activities (OECD, 1999, p. 60).

According to the international body, scientific literacy involves the use of 'key scientific concepts' in order to understand and help make decisions about the natural world. It also involves being able to recognise scientific questions, use evidence, draw scientific conclusions and communicate these conclusions. The OECD/PISA’s view of scientific literacy is quite consistent with those of others stated earlier in this review; it represents a strong international agreement about the nature and importance of scientific literacy as an outcome of schooling.
The notion of scientific literacy is very important. Many authors and science educators agree that it is not only important that new generations of practicing scientists be highly competent, but that, in one way or another, the level of scientific literacy of the general populace should also be a major concern of modern society. Sagan (1995) emphasises this line of thought in the introductory part of his book:

...the consequences of scientific illiteracy are far more dangerous in our time than any that has come before. It's perilous and foolhardy for the average citizen to remain ignorant about global warming, say, or ozone depletion, air pollution, toxicant radioactive wastes, acid rain, topsoil erosion, tropical deforestation, exponential population growth... Jobs and wages depend on science and technology... (p. 6).

Trefil (1996) seemingly states the same issue more succinctly: "...a person is scientifically literate if he or she has enough background in science to deal with the scientific component of issues that confront him or her daily..." (p. 543). This view also is shared by Bybee (1997) for whom the most promising solution to the problem of scientific literacy is curriculum organised according to one or more of the various 'flavours' of Science-Technology-Society approaches. In his extensive discussion of scientific literacy, Bybee (1997) suggests a framework, which exemplifies how scientific literacy can develop and deepen. He explains that the degree of scientific and technologic literacy demonstrated by any individual at any time is a function of many factors, such as age, developmental stage, life experiences, and quality of science education. Science education according to Bybee includes all of an individual's formal, informal, and incidental learning experiences about science. He distinguishes between nominal, functional, conceptual and procedural, and multidimensional scientific literacy: four levels which progress from simple recognition of scientific terms to a high level of scientific literacy in which individuals understand the philosophical, historical, and social dimensions of the discipline. The multi-dimensional level being the level where individuals should have developed a reasonable level of understanding and appreciation of science and technology, as a whole, as part of culture, and be able to make connections between science and technology and larger social problems and aspirations. This notion of progressive development in scientific literacy is fundamental to the development and growth of students' knowledge and understanding of science as they move through schooling.
Even though, there is no complete agreement on the meaning of scientific literacy among science educators (Bybee, 1997; Hurd, 1998), several aspects of scientific literacy are commonly identified. First, scientific literacy includes broad conceptual understandings that enables citizens to comprehend media reports on science related issues, and scientific ways of thinking, including investigating and handling evidence in daily life. Second, scientific literacy may be valued either as an individual’s intellectual capability or accomplishments or primarily for its value in building socially responsible and competent citizenship in a democratic society.

Various views and perspectives about scientific literacy have been discussed in this section. Many countries include scientific literacy as an educational goal because it is regarded as fundamental not only to the development of individuals but also to the technological growth and development of any nation. Achievement of scientific literacy is grounded on effective science teaching and learning in schools. The next section focuses on effective science teaching and learning.

**Effective Science Teaching and Learning**

If science teachers are to teach for understanding, they must be prepared to adapt much of the content in student texts and many of the activities suggested in teachers’ manuals to make them more suitable for the context of students’ experiences (Good & Brophy, 1991). This modern view of the teacher as a decision maker and curriculum developer suggests that science teachers need not only have sufficient content knowledge but also knowledge of a variety of instructional methods and awareness of when and why such methods are used (Good & Brophy, 1991). Past debates on instructional methods indicates that often they were based on dichotomies (e.g. open or traditional methods), as if the goal were to discover the single best way to teach at all times, when in fact different curricula, students, goals and many other variables call for various instructional methods. Since the 1980s research on science teaching has shifted focus from examination of teachers’ behaviour to a view of the teacher as decision-maker who creates a classroom environment that facilitates students’ understanding of subject matter (Shulman, 1986).
The past years have witnessed a rapid growth in research, which examines classroom processes. Progress in this type of research has been enormous and variously documented (Hashweh, 1996; Ravitz, Becker & Wong, 2000; Richardson, 1996). Today the literature includes replicated findings showing how changes in instructional behaviour can improve student learning of science (Gage & Needels, 1989).

This section of the literature review considers instructional issues, strategies and classroom behaviours. The discussion focuses on science teaching through inquiry, constructivist teaching and learning, effective teaching behaviour, student learning behaviour and assessment of learning outcome. These issues are regarded as fundamental to effective science teaching and learning.

Science Teaching through Inquiry

The process of inquiry as it occurs in science classrooms is complex and variable. Inquiry should not be reduced to a set of steps called the scientific method. The processes of inquiry must be taught, practiced and learned, but the reason for engaging students in inquiry goes beyond the development of isolated skills to the inculcation of approach and attitude toward engagement with the world (Haury, 1992). Presenting the Scottish Council for Research in Education's perspective of inquiry in science teaching and learning, Harlen (1996) states:

...inquiry is a major means for learners to extend their understanding of the natural and made environment. It is essentially active learning, inseparably combining both mental and physical activity. The motivation for inquiry is within the learner and the learner's relation to the things around him or her, it starts with something that intrigues, that raises a question in the mind of the learner, something that is not presently understood...The process of inquiry involves linking previous experience to the new experience in an attempt to make sense of the new (p. 2).

DoBoer (1991) states: "if a single word had been chosen to describe the goals of educators during the past 30 years period that began in the 1950s, it would be inquiry" (p. 206). The US Department of Education and the National Science Foundation (1992) together endorsed science curricula that "promote inquiry, problem solving and other
instructional methods that motivate students” (p. 21). Likewise, the National Committee
on Science Education Standards and Assessment (1992) has said, one goal of science
education is “to prepare students who understand the modes of reasoning of scientific
inquiry and can use them” (p. 5). Science teaching by inquiry is therefore fundamental
to promoting scientific literacy.

Dewey (1958) describes inquiry as a dialectical relationship between the inquirer and
the inquired. Keller (1985) describes the relationship as dynamic objectivity. Research
on teaching through inquiry reflects the dynamic and multifaceted nature of this
construct. Bybee (1997) indicates that students should be encouraged to learn to think
and act in ways associated with the processes of inquiry: asking questions, planning and
conducting an investigation using appropriate tools and techniques, thinking critically
and logically about the relationships between evidence and explanations, constructing
and analysing alternative explanations and communicating scientific arguments. Schino
(1996) describes inquiry as:

a process of pursuing a question and figuring out the solutions to
problems through a process of observation, development of explanations
(theories), testing these through experimentation, discussing the outcome
and adjusting theories based on the outcome...Embedded in all these is
the assumption that the classroom is a place in which students feel safe to
articulate ideas without fear of ridicule or judgement; a place in which
they know their comments will be given serious consideration and
respect (p. 1).

Inquiry involves the development and use of higher order thinking to address open­
ended problems. The path to a solution to such problems is not discernible from a single
vantage point. Multiple solutions are possible, and the inquirer may have to use
multiple, some times conflicting criteria to evaluate his or her options. Inquiry is
characterised by a degree of uncertainty about outcomes. Traditionally, critical thinking
has been embedded in the application of the various science processes. Schwab (1962),
for example, wanted instructional laboratories to offer opportunities for miniature
scientific investigations. To that end, he proposed that science teachers present
laboratory problems at three levels in developing an orientation to inquiry. At the first
level, teachers present problems not discussed in the text, with description of different
ways to approach the solution. At the second level, teachers pose problems without methodological suggestions. At the third level, teachers present phenomena designed to stimulate problem identification. Each level requires more facility in using process skills than the previous level.

Trowbridge and Bybee (1990) also discuss three levels of inquiry, beginning with discovery learning, in which the teacher sets up the problem and processes but allows the students to identify alternative outcomes. The next level of complexity is guided inquiry, in which the teacher poses the problem and guides the students to determine both the processes and solutions. The third and most demanding level is open inquiry, in which the teacher merely provides the context for identifying problems that students can identify and solve. A scale devised by Schwab in 1962 that describes levels or openness of inquiry has been elaborated (Tamir, 1989) to vary from the zero to the third levels of inquiry. At the zero level of inquiry, the problem to be investigated, the equipment to be used, the method to follow and the answer to the problem are all given to the students by the teacher or by the worksheet. This level corresponds to the verification of scientific results, which is common in the traditional transmission models of classroom teaching and learning (Tamir, 1989). According to the scale, the next level (level 1) in which only the answer is left open corresponds to the guided inquiry while the second level, in which both the method and the answer are left open, corresponds to the open-guided inquiry. At the highest level of inquiry (level 3), the students are required to determine all of these things for themselves.

Garnett, Garnett & Hackling (1995) describe a science investigation “as a scientific problem which requires the student to plan a course of action, carry out the activity, collect the necessary data, organise and interpret the data and reach a conclusion which is communicated in some form” (p. 27). Hackling (1998) argues that modelling, coaching and scaffolding are important strategies to support students conducting open investigations.

Since science teaching by inquiry (from the constructivist perspective) is to lead students to construct their own understanding, questioning is an important skill. Open questions promote inquiry and often lead to conceptual discussion. It is also important to encourage students to ask questions and help them to frame questions. Questions that
promote inquiry and lead to conceptual discussion are important for the success of inquiry teaching and learning in science (Dantonio, 1987).

More recently, inquiry has been viewed as having a discursive and social dimension (Klaassen et al., 1996; Tobin et al., 1997) that complements the dimensions of critical thinking and individual skill with science processes. Studies of small group interactions have revealed the power of verbal expression and social interaction to promote inquiry and student engagement. Teachers use small group interactions to stimulate discussion, increase engagement with materials, distribute responsibility for functions of activities, and distribute expertise around the class. These actions are particularly common in laboratory settings or during hands-on activities in science classroom. Student understanding improves when small groups are structured through assigned roles and scripts for reviewing, rehearsing and discussing results (Cohen, 1994).

It should be noted, however, that a science teacher who provides too much structure for a task might defeat the purpose of inquiry. Cohen (1994) states a subtle but important dilemma for teachers that have implications for conducting small group instructions in science:

If teachers do nothing but supply the task, the students may focus on the mundane or concrete features of the problem without exploring its more abstract and, presumably, more meaningful aspects. If teachers do too much by assigning roles and responsibilities, they may destroy opportunities for students to carry out inquiry and express novel approaches or ideas (p. 10).

It is important in closing that inquiry-based instruction can have three meanings in practice. Inquiry-oriented instruction can mean teaching about the nature and processes of scientific inquiry, being in that sense a learning outcome. Furthermore, it can mean that students learn science concepts by using the processes of scientific inquiry. In this sense, it is a means to achieve an end. It can also mean that students, in an appropriate environment, learn to identify problems and also provide the processes of providing the solution to the problem. This learning is associated with an open inquiry or an open investigation strategy. Science teachers are more likely to use didactic teaching methods when teaching about inquiry by introducing key terms and providing guided practice. The application of inquiry as a teaching method is more likely to be indirect, with the
teacher asking more open-ended questions and stimulating more student-to-student discussion (Brophy & Good, 1986).

The need for science teachers to see science as inquiry and to teach through inquiry has been discussed in this section. Science teachers should know that inquiry is process driven and involves students' interest or passion to explore their natural or material world. As the processes of inquiry unfolds, more observations and more questions emerge, giving occasion for deeper interactions between the students with the teacher acting as a guide. Teachers can teach about the nature and processes of inquiry; students can learn science concepts through the processes of inquiry. The level of inquiry in science teaching and learning varies from verification of scientific facts through guided inquiry to open inquiry. Students must be encouraged to learn to think and act in ways associated with inquiry. An inquiry-based approach is fundamental to effective science teaching and learning.

Constructivist Teaching and Learning

Constructivism is basically a theory about how people learn. It is a view of learning based on the belief that knowledge is not a thing that can be transmitted by the teacher to the student. Rather, learners through an active, mental process of development construct knowledge; learners are builders and creators of meaning and knowledge. Resnik (1983) asserts: “meaning is constructed by the cognitive apparatus of the learner” (p. 477). In Von Glasersfeld's (1990) view, "knowledge is not a commodity which can be communicated" (p. 3).

Fosnot (1996) defines constructivism by reference to four principles: learning, in a way, depends on what we already know; new ideas occur as we adapt and change our old ideas; learning involves inventing ideas rather than mechanically accumulating facts; meaningful learning occurs through rethinking old ideas and coming to new conclusions about new ideas which conflict with our old ideas. Steffe (1990) explains that constructivists view learning as the adaptations children make in their functioning schemes to neutralise perturbations that arises through interactions with our world. The basic tenets of constructivism are that learners' past experiences, including feelings, are organised into related ideas called schemes that are used to interpret and make sense of new experiences (Osborne & Freyberg, 1985). Constructivism examines the ways in
which learners make meaning from experience. Learners do not transfer knowledge from the external world into their memories; rather they create interpretations of the world based on their past experiences and their interactions in the world. Cunningham (1992) asserts: “how someone construes the world, their existing metaphors, is at least as powerful a factor influencing what is learnt as any characteristics of that world” (p. 36).

Constructivism draws on the developmental work of Piaget (1977) and Kelly (1991). Piaget (1977) asserts that learning occurs by an active construction of meaning, rather than by passively receiving it. He explains that when, as learners, encounter an experience or a situation that conflicts with our current way of thinking, a state of disequilibrium or unbalance is created. We must then alter our thinking to restore our equilibrium or balance. To do this, we make sense of the new information by associating it with what we already know, that is, by attempting to assimilate it into our existing knowledge. When we are unable to do this, we accommodate the new information to our old way of thinking by restructuring or changing our present knowledge to a higher level of thinking.

Similarly, Kelly (1991) in his theory of personal constructs proposes that people look at the world through mental constructs or patterns that they create. Kelly explains that people develop ways of understanding the world based on their experiences; when people encounter a new experience, they attempt to fit these patterns over the new experience.

Constructivists view science “not as a body of knowledge existing separate from the knower but as a set of socially negotiated understandings of the events and phenomena that comprise the experienced universe” (Tobin & Tippins, 1993, p. 4). Scott (1987) defines a constructivist in science as one who “perceive students as active learners, who come to the science lessons already holding ideas about natural phenomena, which they use to make sense of everyday experiences... such a process is one in which learners actively make sense of the world by constructing meaning” (p. 10).

Airasian and Walsh (1997) assert that constructivism is a learning theory and not an instructional strategy and that science teachers can teach in ways which are called ‘constructivist’ by being aware of, and teaching in a manner consistent with how their
students learn. Employing the constructivist approach in science teaching requires different strategies from those usually followed in science classrooms (Brooks & Brooks, 1993; Sivertsen, 1993). In most classrooms in Nigeria, the teacher's role is mainly directive and rooted in authority. The teacher disseminates information to students; students are recipients of knowledge.

Fosnot (1996) recommends that a constructivist approach be used to create learners who are autonomous, inquisitive thinkers who question, investigate and reason and that this approach frees teachers to make decisions that will enrich students' development in these areas. Science teachers need to recognise how students use their own experience, prior knowledge and perceptions as well as their environment to construct knowledge and meaning. This perspective of learning presents an alternative view of what is regarded as knowledge (Tobin & Tippins, 1993; Von Glasersfeld, 1995), suggesting that there may be many ways of interpreting or understanding the world. The teacher is no longer seen as an expert who knows the answers to questions he/she has constructed, while students are asked to identify their teacher's constructions rather than to construct their own meanings. In a constructivist classroom, students are encouraged to use their prior experience to help them form and reform interpretations. The teacher through dialogue helps students to construct their own knowledge; his/her role is interactive and rooted in negotiation (Von Glasersfeld, 1996).

A constructivist classroom is student-centred since it places more focus on students' learning than on the teacher's teaching. Linfors (1984) advises that how teachers teach should originate from how students learn. Ideas are negotiated in a constructivist classroom. This tends to unite student and teachers in a common purpose. Smith (1993) asserts that negotiating curriculum means, "custom-building the class everyday to fit the desires of individuals who attend" (p. 1). Boomer (1992) asserts that it means:

a deliberate plan to invite students to contribute and to modify the educational program so that students have real investment both in learning and outcome. Negotiation also means making explicit, and confronting the constraints of learning context and the non-negotiable requirements that apply (p. 14).
Cook (1992) explains that negotiation of curriculum makes learners work harder and better and that what they learn will mean more to them if they are developing their own ideas, asking their own questions and striving to answer them for themselves. He asserts: "out of negotiation comes a sense of ownership in learners for the work they are to do, and therefore a commitment to it" (Cook, 1992, p. 16).

Lester and Onore (1990) suggest that a teacher's constructivist beliefs, specifically those related to the belief of students' as constructors of knowledge, make it possible to create a democratic environment for learning. They describe a democratic classroom as 'self-regulating' in the sense that the teacher only needs to structure the classroom such that both teacher and students share in the control. A constructivist teacher offers his/her students option of choices in their work, engages their trust and invite them to participate in processes that allow them to be involved in decisions about their learning. However, those choices may be contained within parameters set by the teacher (Sheridan, 1993). A constructivist teacher does not wield power in the classroom and control is not imposed on the students. Instead, he/she uses an indirect control and empowers students by involving them, by giving them responsibility and by encouraging them to be autonomous and self-controlling.

This aspect of the review has been focused on the definition and rationale for constructivist teaching and learning. Some characteristic features of a constructivist classroom are also examined. The discussion indicates that teachers' beliefs and ideas about constructivism and about how students learn in science can shape their instructional strategies. It also indicates that constructivist teaching and learning fosters critical thinking, creates active and motivated learners, gives students ownership of what they learn, stimulates and encourages students and promotes social and communication skills by creating a classroom environment that emphasises collaboration and exchange of ideas. These goals are consistent with those stated in the current Nigerian Integrated Science curriculum for junior secondary schools (FME, 1984). The next section further explores effective classroom behaviour in science teaching and learning.
Effective Teaching Behaviour

Planning a lesson involves a number of instructional decisions. Science teachers must be able to identify the content and processes to be addressed, the strengths, needs and interests of learners and the most effective instructional approaches. Teachers should understand that such decisions are critical and must be made consciously and purposefully. In his view of effective teaching, Glickman (1991) states:

Effective teaching is not a generic practice, but instead a set of context-driven decisions about teaching. Effective teachers do not use the same set of practices for every lesson.... Instead what effective teachers do, is constantly reflect about their work, observe whether students are learning or not, and, then adjust their practice accordingly (p. 6).

Because there are so many variables for teachers to consider when making decisions about teaching and learning, it is essential that they understand the various levels of instructional decision-making. These levels of instructional approaches range from instructional model, strategies, to instructional skills, which represent a specific teaching behaviour or technique. Within each level the potential exists for the teacher to develop the science or the art of teaching (Arends, 1988).

Instructional models represent the broadest levels of instructional practices and present a philosophical orientation for instruction (Borich, 1988). Models are used to select and structure teaching strategies, methods, skills and student activities for a particular instructional emphasis. Joyce and Weil (1986) identify four instructional models: information processing, behavioural, social interaction, and personal. Within each instructional model the teacher can make use of several strategies. Strategies determine the approach the teacher makes to achieve learning objectives and they can be classed as direct, indirect, interactive, experiential or independent (Joyce & Weil, 1986). Instructional methods in turn, derive from the teacher's adopted strategy, and are used by the teacher to create learning environments and to specify the nature of the activity in which the teacher and learner will be involved during the lesson (Borich, 1988). While particular teaching methods are often associated with certain strategies, some methods may be found within a variety of instructional strategies. Instructional skills are the
most specific instructional behaviours (Arends, 1988). These include such techniques as questioning, discussing, direction giving, explaining, and demonstrating. Instructional skills also include such teacher actions as planning, structuring, focusing and managing.

Direct instruction is highly teacher-directed and is among the most commonly employed by science teachers (Odubunmi & Balogun, 1991; Okebukola & Jegede 1988). This strategy includes methods such as lecture, didactic questioning, explicit teaching, drill and practice and demonstrations. Direct instruction may be effective for providing information or developing step-by-step skill and for introducing other teaching methods or actively involving students in knowledge construction (Henson, 1988). However, teachers need to recognise the limitations of its predominant use for developing abilities, processes, and attitudes required for critical thinking, and for interpersonal or group learning. Inquiry, induction, problem solving, decision-making, and discovery are terms that are sometimes used interchangeably to describe indirect instruction (Martins, 1983). In indirect instruction, the role of the teacher shifts from that of a lecturer/director to that of a facilitator, supporter, and resource person. The teacher arranges the learning environment, provides opportunity for students' involvement, and, when appropriate, provides feedback to students while they conduct the inquiry (Martins, 1983).

Teachers also usually employ an interactive instructional strategy, which relies heavily on discussion and sharing among participants. Seaman and Fellenz (1989) suggest that discussion and sharing provide learners with opportunities to "react to ideas, experience, insights, and knowledge of the teacher or of peer learners and to generate alternative ways of thinking and feeling" (p. 119). The success of interactive instruction and its many methods is heavily dependent on the expertise of the teacher in structuring and developing the dynamics of the class. The strategy allows for a range of groupings and interactive methods.

Teachers also make use of experiential learning as an instructional strategy. This strategy is effective if 'hands-on' experience is needed and in a situation where the teacher is required to motivate the students to actively participate and teach one another by describing what they are doing (McNeil & Wiles, 1990). According to Pfeiffer and Jones (1979), experiential learning occurs when learners participate in activities, critically reflect on their work, draw useful insights from such analysis, and are able to
put what they have learned into practice in new situations. Teachers can make use of experiential learning as an instructional strategy both in and outside of the school.

A primary educational goal is to help learners become self-sufficient and responsible citizens by enhancing their individual potential. Teachers can help students to grow as independent learners. If the knowledge, abilities, attitudes, and processes associated with independent learning are to be acquired, the teacher must teach them and enough time must be provided for learners to practice (Roth, Anderson & Smith, 1987). Teachers can employ independent study as an instructional strategy for the whole class, in combination with other strategies, or it can be used with one or more individuals while another strategy is used with the rest of the class. Students should be able to continue to learn after they have left the structured learning environment of the school (AAAS, 1993).

After deciding on appropriate instructional strategies, the teacher must make decisions regarding appropriate instructional methods. As in the case with strategies, the distinction between methods is not clear-cut. Teaching methods usually employed by teachers vary significantly and may range from the lecture, concept formation, inquiry, reflective study, concept mapping, concept formation, field observation, demonstration, computer assisted instruction, discussion, question and answer, cooperative learning and so on to simulations (Lawson & Thompson, 1988; Peters, 1982; Wandersee, Mintzes & Novak, 1994; Zoller, 1990). Although there are many ways to teach science effectively, all require that the teacher have knowledge of three things: the material being taught; the best instructional strategies to teach the material; and how students learn (Lord, 1994). New teachers typically know far more about the content of their discipline than they do about instructional strategies, and therefore tend to use teaching styles similar to those used by their own teachers (Shulman, 1990). In most cases, they use elements of all three general teaching styles: discipline-centred, teacher-centred and student-centred teaching, and as they gain experience their teaching styles tend to change.

From the constructivist perspective, the role of the teacher is to organise information around conceptual clusters of problems, questions and discrepant situations in order to engage the students' interest. Their roles include assisting the students in developing new insights and connecting them with their previous learning. Postlewaite (1993) asserts:
Teachers should present ideas holistically as broad concepts and have it broken down into parts. The activities are student-centred and students are encouraged to ask their own questions, carry out their own experiments, make their own analogies and come to their own conclusion (p. 2).

Clearly, a lesson based on constructivist learning differs greatly from the traditional teacher-centred type. The first objective in a constructivist lesson is to engage students' interest on topic that has a broad concept. The teacher should seek and use students' questions and ideas to guide the lesson, accept and encourage students initiation of ideas, and encourage the use of alternative sources of information and so on (Yager, 1991).

Instructional skills are the most specific category of teachers' teaching behaviours. They are used constantly as part of the total process of instruction and are necessary for procedural purposes and for structuring appropriate learning experiences for the student. Such skills include explaining, demonstrating, questioning, listening, giving feedback, scaffolding, coaching and so on.

Among instructional skills, questioning holds a place of prominence in most classrooms. Good questions should be carefully planned, clearly stated, and to the point in order to achieve specific objectives. Teacher understanding of questioning technique, wait time, and levels of questions is essential. The teacher should also understand that asking and responding to questions is viewed differently by different cultures and must be sensitive to the cultural needs of students (Jegede & Okebukola, 1989).

Several researchers (Kounin & Gump, 1974; Kounin & Doyle, 1975; Reiss, 1982) studied classroom management activities in relation to student achievement. For example, in the Science in a Social Context Project (Layton, 1994), classroom management is seen, among other things, as the device to create time for learning and, more specifically, to ensure that students actually spend time on their tasks. Teachers' management behaviour and instructional behaviour can be said to overlap substantially, both on theoretical grounds and on the bases of analysis of classroom events (Kounin & Gump, 1974).
Indeed, instruction not only requires management and control, but seems to create classroom control as well (Doyle, 1986). Management is an important characteristic of effectiveness, but it should be combined with other characteristics of effective instruction (Pollard, 1982; Pollard & Menter, 1997; Pollard & Tann, 1989).

On the basis of the above argument it could be concluded that teachers' management and instructional behaviour are closely related. Adequate skills in both areas are fundamental to effective science teaching. Opportunities for learning are enhanced by teaching behaviour and by students' approach to learning. Students' learning behaviour is therefore discussed in the next section.

**Students' Learning Behaviour**

How do students learn best? How can understanding of student learning influence science teaching? These are a few questions science educators have begun to ask themselves as they gain more knowledge about how students learn. Most science teachers view knowledge as existing outside the bodies of cognising beings, as being separate from knowing and 'knower'. Knowledge is 'out there', residing in books, independent of a thinking being. Science is then conceptualised as a search for truths, a means of discovering theories, laws and principles associated with reality. Objectivity is a major component of the search for truths, which underlie reality; learners are encouraged to view objects, events and phenomena with an objective mind, which is assumed to be separate from cognitive processes such as imagination, intuitions, feelings, values and beliefs (Johnson, 1987). As a result, science teachers who hold this erroneous view about scientific knowledge tend to implement a curriculum to ensure that students cover relevant science content and have opportunities to learn truths, which, usually, are documented in the texts.

Research (Driver, 1989; Lorsbach & Tobin, 1998; Tobin, 1990) indicates that students have a profound influence on learning outcomes. Reflective teachers have realised for decades that learner plus instruction does not equal intended science outcomes (Fensham, 1983). Constructivist epistemology asserts that students come into the classroom with their own experiences and a cognitive structure based on those experiences. These preconceived structures may either be valid, invalid or incomplete. The learner will reformulate his or her existing structures only if new information or
experiences are connected to knowledge already in memory. Inferences, elaborations and relationships between old perceptions and new ideas must be generated by the student in order for the new idea to become an integrated, useful part of his or her memory. Memorised facts or information that has not been connected with the learner's prior experiences will be quickly forgotten. It is only through seeing, hearing, touching, smelling, and tasting that an individual interacts with the environment and with the messages from the senses the individual builds a picture of the world (Lorsbach & Tobin, 1998; Wheatley, 1991).

Furthermore, cognitive psychologists have stressed that students do not passively receive or copy information they get from the teachers, but instead actively mediate it by trying to make sense of it and relate it to what they already know or think they know about a topic. Thus students develop new knowledge through a process of active construction (Driver, Leach, Millar & Scott, 1996). In order to go beyond rote memorisation to achieve true understanding of new information, learners need to develop and integrate a network of associations linking new information to pre-existing knowledge and beliefs anchored in their memories.

Learning has been described as an active process in which the learner uses sensory input and constructs meaning out of it (Osborne & Wittrock 1983). The more traditional formulation of this idea involves the terminology of the active learner (Dewey's term) stressing that the learner needs to do something; that learning is not the passive acceptance of knowledge that exists 'out there' but that learning involves the learner engaging with the world (Dewey, 1916). Active learning is defined as any strategy that involves students in doing things and thinking about the things they are doing (Bonwell & Eison, 1991). Active learning includes a range of learning activities, which may include students' involvement in activities that make them think about and comment on the information presented to them. The students will not just listen; they will be involved in analysing, synthesising, and evaluating information, in discussion with other students, through asking questions, or through writing. The students will be engaged in activities that force them to reflect upon ideas and upon how they are using those ideas. Active learners are actively involved in the classroom processes, initiate their own activities, make decisions concerning their learning, engage in self-evaluation, display their competences in various ways and feel good about themselves as learners (Bentley & Watts, 1989).
The notion of active learning is also consistent with that of hands-on learning in science. Hands-on science means learning from the materials and processes of the natural world through direct observation and experimentation.

Professional scientists develop hypothesis and then test these ideas through repeated experiments and observations. They cannot simply ‘know’ that something is so; they must demonstrate it. The education of children in science must also provide for this kind of experience, not simply to confirm the ‘right’ answer but to investigate the nature of things and arrive at explanations that are satisfying to children and that make sense to them (National Science Resource Centre, 1988, p. 1).

Rutherford (1993) asserts that hands-on learning activities used appropriately can transform science learning by engaging the students in the processes of science. He reiterates:

Unfortunately, these activities are not widely used. It could be because so few teachers have had the opportunity to develop skills needed for hands-on instruction. Another factor is that hands-on learning takes time... and the pressure to get on with the overstuffed curriculum discourages many teachers from taking that time (p. 1).

In hands-on learning students learn by doing, using materials such as plants, batteries and bulbs, water, or instruments such as microscope, meter rules, or test tubes. Instructional materials must be sequenced to facilitate students' construction of meaning. Students' activities, which lack connections drawn among them, can lead to isolated bits of knowledge or skills, which do not promote understanding, but rather the forming of naive conceptions. Therefore, rather than present students with bits and pieces of information or scientific ideas and leave it to them to piece these together, the teacher needs to help them see the interconnections among those ideas.

Learning is also a social activity (Edwards & Mercer, 1987). Students' learning is intimately associated with their connections with other human beings, their teachers, peers, family as well as casual acquaintances. Therefore, the interactive discourse and activities that occur during science lessons facilitate the construction of meaning.
required to develop understanding. Learners must be provided with the opportunity to ask and answer questions about content, and debate its meaning and implications. These activities allow students to process content actively and to integrate information by relating it in their own words, exploring its relation to other knowledge and to past experience, appreciating the insights it provides, or identifying its implications for personal decision making or action. Much of the traditional education, as Dewey pointed out, is directed towards isolating the learner from all social interactions and towards seeing education as a one-to-one relationship between the learner and the objective material to be learned. In contrast, 'progressive education' recognises the social aspect of learning and uses conversation, interaction with others, and the application of knowledge as an integral aspect of learning (Edward & Mercer, 1987). Learning in science is contextual. As explained by Cole and Griffin (1987):

'We do not learn isolated facts and theories in some abstract ethereal land of the mind separate from the rest of our lives. We learn in relationship to what else we know, what we believe, our prejudices and our fears. On reflection, it becomes clear that this is a corollary of the idea that learning is active and social. We cannot divorce learning from our lives (p. 8).

The action of constructing meaning by the learner is a mental activity; it happens in the mind; physical actions, hands-on experiences though very necessary for learning especially for children, is not usually sufficient, science teachers need to provide activities which engage the mind as well as the hands (Henriques, 1997). Dewey (1916) called this reflective activity. Furthermore, motivation is a key component in science learning. The idea of motivation as described in this review is broadly conceived to include an understanding of ways in which the knowledge learned can be used. Unless the learner knows the 'reason why?' he/she may not be very involved in using that knowledge that may be instilled in him or her, even by the most severe and direct teaching (Henriques, 1997). Therefore new scientific knowledge and ideas should be introduced using issues that are relevant to and meaningful in students' lives. Sometimes integrating science activities and content with other learning areas may serve to make the process of learning science more relevant to students.

In summarising, the on-going discussion reveals that students learn through a process of active construction. Learning is not a passive acceptance of information; learners
construct meanings out of it. Active learners are actively involved in the classroom processes grounded in social interactions and are also involved in the processes of self-assessment. Discussed in the next section is how assessment can improve science teaching and learning.

Assessment of Learning Outcomes

Assessment is an integral part of teaching and learning process and it should enhance the quality of both teaching and learning. Assessment in science is the collection and interpretation of information about learner's knowledge, understanding, skills and attitudes relating to the science outcomes. It refers to alignment of goals, instruction and outcomes with respect to the intellectual, social, and personal development of the learner in all aspects of science (Miller, 1996). The three main purposes for assessment are concerned with the support of learning, reporting the achievement of individuals and satisfying the demands of public accountability (Goodrum et al., 2001). Summative assessment indicates how well something has been learned after teaching has been completed, whereas formative assessment provides feedback to both the teacher and the learner during the process of teaching (Biggs & Moore, 1993). The information from summative assessment is used to report progress to students, parents and others, and contribute to establishing accountability. Information from formative assessment provides feedback, which informs the future action of both learners and teachers (Black, 2003; Black & Wiliam, 1998).

Assessment is the first step in a continual learning cycle, which includes measurement, feedback, reflection, and change (Frye, 2001). The purpose of assessment is not just to gather information; it is to foster improvement (Miller, 1996). Frequent assessment of students helps them to refine concepts and deepen their understanding; it also conveys high expectations, which further stimulates learning. Wiggins (1997) asserts: “students overwhelmingly acknowledged that the single most important ingredient for making a course effective is getting a rapid response from assessments” (p. 11).

Paper and pencil testing has been and continues to be the dominant assessment method for outcomes of formal education, and acquisition of content is often the dominant goal. However, most educators acknowledge that written tests assess only a very limited
range of students' abilities and may restrict the ability of capable students to express themselves in other mediums (NRC, 1996).

Assessment is not a punitive action. Its purpose is not to catch and punish students who have not learned. Instead, assessment is a process of learning by both the teacher and the student. Good assessment strategies help students learn about their strengths and weaknesses, building upon the former and remedying the latter. Assessment has failed when it results only in a sense of failure or incompetence for sincere students. As Webb (1997) notes, “we must measure what we claim to value as student skills, including ability to contribute productively as members of society” (p. 3).

A variety of assessment tasks accommodate preferred learning styles and differences among learners in order to give them the opportunities to demonstrate what they know and can do in science. Opportunities can be provided to the teachers and students to negotiate the nature of assessment tasks and the way in which the tasks will be conducted.

Many efforts are currently underway to develop methods to authentically assess the knowledge and skills of students. Central to the process of authentic assessment is the concept of alignment, which refers to consistency between goals, actions and assessments (NRC, 1996). A relevant question to ask when aligning instruction, goal and assessment is: Is instruction likely to lead to attainment of the identified goals? Assessment may be invalid if it (a) does not address the content in the assessment; (b) does not align the assessment with the goals; (c) does not align assessment with the way instruction takes place (Webb, 1997). In a climate of positive assessment, learners and their teachers look for evidence to document growth and for new ways to show what students can do.

The effectiveness of formative assessment in improving learning outcomes is strongly related to the quality of the feedback given to the learner following the assessment (Black & Wiliam, 1998) and the action taken by the students in relation to the feedback. Portfolios are often used to collect evidence of growth and change. Multiple assessment methods including demonstrations, practicum observation, discussion, reports, simulations, exhibitions and many other outcomes are useful alternatives to the traditional written tests. Peer assessment in cooperative learning groups is especially
useful for assessing demonstrating skills using laboratory equipment and other practical skills.

Involving students in designing the rubrics that will be used to assess their work is often effective. Anderson and Page (1996) provide examples of how this can be done. They assert that preparation of teachers should include opportunities for them to take part in designing and defending rubrics of their own reflective self-assessment. Reflective teachers continually seek evidence for their own success in helping their students achieve learning objectives. They may use audio and video recordings to examine their performance and often invite peers, and supervisors to observe them and make suggestions for improving their practices. They frequently construct professional portfolios with artefacts and reflective commentary, recording their perceptions of their success and failure as a teacher. Such teachers use information about how students are doing ‘on the average’ to analyse the success of their instructional strategies. They know how to align instructional practices and materials with outcomes as measured on carefully selected assessment instruments (Webb, 1997).

This discussion of assessment indicates that it is an integral part of teaching and learning in science. The types of assessment and their purposes have also been outlined. Both the teacher and the students should be involved in the process of assessing learning outcomes. Effective science teaching is grounded on teachers’ self-assessment and personal reflections about their failures and successes and these in turn inform their future actions.

**Teachers’ Beliefs and their Influence in Science Teaching**

This section represents the third part of the literature review. It focuses on teachers’ beliefs system, beliefs about the nature of science and science teaching, beliefs about their students, and beliefs about cultural issues that may impact on science teaching and learning.

**Teachers belief system**

Beliefs are mental constructs that represent the codification of people’s experiences and understandings. Theorists generally agree that beliefs are created through a process of
enculturation and social construction (Pajares, 1992). People's beliefs shape what they perceive in any set of circumstances, what they consider to be possible or appropriate in those circumstances, the goals they might establish in those circumstances, and the knowledge they might bring to bear in them (Schoenfeld, 1998).

In the cognitive science literature, there is a significant amount of research on individual belief systems. Belief systems are regarded as integrated systems of concepts, scripts and scenes that lend meaning to the action systems of classrooms (Gentner & Gentner, 1983). Clark (1988) defines teachers belief system as “eclectic aggregations of cause effect propositions from many sources, rules of thumb, generalisations drawn from personal experience, values biases, and prejudices” (p. 5).

Clark and Peterson (1986) adopted the sociocultural approach in their definition of teachers’ belief system. They define it as: “a reflective, socially defined interpretation of experience that serves as a basis for subsequent action... a combination of intentions, interpretations, and behaviour that interact continually” (p. 28). They assert that teachers' beliefs are seen as situation-specific and action oriented and include both the beliefs teachers have about their work including goals, purposes, conceptions of children, curriculum, and the “way in which they give meaning to these beliefs by their behaviour in the classroom” (p. 28). Science teachers’ beliefs, like all cognitive processes, can only be inferred from behaviour.

One of the difficulties in examining science teachers’ beliefs, in addition to the fact that they are not directly observable, is that there is some disagreement over the differences between beliefs and knowledge (Clandinin & Connelly, 1987). For instance, Nespor (1987) asserts that beliefs are basically unchanging, and, when they change, it is not argument or reason that alters them but rather a “conversion or gestalt shift” (p. 321). According to him, knowledge systems are open to evaluation and examination; beliefs are not. Nespor (1987) added that belief systems are unbounded in that their relevance to reality defies logic, whereas knowledge systems are better defined and receptive to reason.

There is increasing recognition, particularly among educators, that the beliefs that individuals hold are the best indicators of the decisions that they make during the course of everyday life (Bandura, 1986). Beliefs are instrumental in defining tasks and in
selecting the cognitive tools with which to interpret, plan, and make decisions regarding such tasks; hence they play a critical role in defining behaviour and organising knowledge and information (Abelson, 1979; Bandura, 1986; Lewis, 1990; Schommer, 1990).

Educational researchers trying to understand the nature of teaching and learning in classrooms have usefully exploited this focus on belief systems. They have used teacher beliefs as a tool to understand why teachers act, react, and implement science education reforms efforts (Beck & Lumpe, 1996). There is a growing body of literature that suggests that the beliefs teachers hold impact on both their perceptions and judgements, and that these in turn affect their behaviour in the classroom. Further, changing these belief systems is an essential part of improving both professional and teaching effectiveness (Ashton, 1990; Ashton & Webb, 1986; Brookhart & Freeman, 1992; Buchmann, 1984; Cole, 1989; Goodman, 1988).

Teachers hold many untested assumptions that influence how they think about classroom matters and respond to particular situations. Little has been written on qualitative differences in types of belief, although there are five main areas in which teachers have been found to hold significant beliefs - about learners and learning, teaching, subject, learning to teach, and teaching role (Calderhead, 1996). Such areas, however, could well be interconnected, so that beliefs about teaching, for instance, may be closely related to beliefs about learning and about the subject.

In his study towards a theory of teaching-in-context Schoenfeld (1998), asserts that the following classes of beliefs affect teachers' classroom actions and should be examined in a comprehensive model of teaching:

- beliefs about the nature of subject matter in general and with regards to specific topics being taught;
- beliefs about the nature of learning process, both cognitive and affective;
- beliefs about the nature of the teaching process and the roles of various kinds of instruction; and
- beliefs about individuals and classes of students (p. 3).
Hashweh (1996) determined that teachers holding constructivist beliefs were more likely to detect students' alternative conceptions; have a richer repertoire of teaching strategies; use potentially more effective teaching strategies; report more frequent use of effective teaching strategies; and highly evaluate these teaching strategies compared with teachers holding empiricist beliefs. Brickhouse (1990) also found that the classroom actions of two experienced teachers reflected their beliefs of what science is and how students learn science. However, a beginning teacher in the study used unpredicted actions that were not aligned with his beliefs. Pajares (1992) found that understanding the belief structure of in-service and prospective teachers was fundamental to improving their professional development and teaching practices.

Findings from the studies by Abelson (1979), Buchmann (1984), and Buchmann and Schwille (1983) reveal that beliefs are formed early and tend to self-perpetuate, persevering even against contradictions caused by reason, time, schooling, or experience. According to the findings by Clark (1988), Lewis (1990), and Munby (1982), the earlier a belief is incorporated into the belief structure, the more difficult it is to alter. They assert that newly acquired beliefs are most vulnerable to change.

In the framework provided by Hofer and Pintrich (1997), the structure of beliefs is considered to comprise core and peripheral beliefs whereby the peripheral beliefs are filtered by core beliefs. The more a belief is connected with other beliefs within the belief system, the more central the belief and the more impervious to change (Pajares, 1992; Peterman, 1991).

Teachers' beliefs are often context-dependent argues Schoenfeld (1998); they have differing strengths in differing contexts and they tend to be activated in clusters. One highly activated belief may trigger the activation of other closely related beliefs and conflicting beliefs can 'compete' for priority, he explains. Brownlee and Carrington (2000) explain that beliefs relating to individual learning, such as learning strategies, motivation, influences on learning and conceptions of learning, are more likely to change depending on the particular learning context. For example, a teacher may be introduced to a new approach as a result of workshop or in-service training, which he/she tries out in the classroom with a positive response from students. This, in turn, reinforces that particular classroom practice with subsequent effects on the teacher's beliefs about teaching, understanding of the nature of the subject and hence his PCK.
Furthermore, a student may surprise a teacher with some comment or a piece of work. This may become a growth point for change in the teacher's beliefs about the teaching context, about his students and about teaching.

Beliefs and PCK are inextricably intertwined (Veal, 1998). Beliefs inform teachers' classroom practice and knowledge gained in the classroom or through in-service training informs teachers' beliefs; the teachers' knowledge base also informs his/her PCK (Carlsen, 1999). Veal (1998) states that the relationship between teachers' beliefs and PCK is synergistic and that such a relationship creates a unified understanding of their teaching practice.

There are factors which may enable or constrain how the teacher implements his/her beliefs. The teacher's science background, peers, and personal traits may facilitate the translation of his/her beliefs into practice (Palmer, 1990). Context, socio-cultural and institutional factors may constraint the implementation of teacher's beliefs into classroom practice (Palmer 1990; Roth & Roychoudhury, 1994).

The discussion in this section points to the fact that the beliefs of teachers can inform educational practices in many ways. Beliefs can be identified that are consistent with effective teaching practices and student cognitive and affective growth. Science teachers' beliefs are instrumental in defining teaching and learning tasks, in selecting cognitive tools, in planning for instruction, and in adopting teaching strategies. Teacher's beliefs are often context specific. A teacher's personal beliefs about effective or good science teaching lies at the heart of his or her teaching practices.

Beliefs about the Nature of Science and Science Teaching

Science teachers hold varying beliefs about the nature and purpose of teaching. Some may view teaching as a process of knowledge transmission, others as a process of guiding children's learning. Some teachers may view teaching more in terms of developing social relationships in a classroom community; others may see their task in much more academic terms.

Several studies suggest that student teachers frequently start professional training with views of teaching as telling and learning as remembering (Calderhead, 1988; Russel,
1988), and this presents difficulties when student teachers are encouraged to adopt a more constructivist approach towards science teaching and learning in which children's own commonsense thinking is recognised and challenged (Stoddart, 1992).

Student teachers' belief systems about science teaching have been assessed using the Context Belief About Teaching Science (CBATS) attitude scale (Hoy & Rees, 1977). Such studies have typically found that student teachers start with control-oriented belief systems that emphasise the importance of maintaining order and good discipline and guiding the activities of the children. These attitudes change slightly during training, becoming more liberal and child centred in the course of training. But when science teachers enter full-time teaching they revert to control-oriented belief system again (Lacey, 1977).

Such findings have often been interpreted in terms of a powerful control-oriented ideology that exists within schools and reinforces the beliefs that student teachers have acquired from being students themselves. Findings from the study of Lawrence (1992) suggest that many student teachers hold beliefs that learning and teaching involve a process of transmitting information from the teacher to the learner. When individuals hold such beliefs they are more likely to adopt surface approaches to teaching and learning (Marton & Saljo, 1976) which are considered to result in fragmented learning outcomes. Therefore, science teachers should be encouraged to develop transformative beliefs about teaching and learning (Marton & Saljo, 1976). The transformative belief is consistent with the constructivist teaching involving an active engagement of students, for whom they are responsible, in the process of making meaning (Lawrence, 1992).

Findings from the study by Lederman (1992) indicate that only experienced teachers exhibit beliefs of the nature of science consistent with those identified in the various reforms i.e., views consistent with the contemporary views of science. However, the study shows that less than 50% of them exhibit classroom practices consistent with their professed views about the nature of science. That is, few teachers included many inquiry-oriented activities that require students to collect data and infer explanations from the data that had been collected. None of the teachers studied ever had students' understanding of the nature of science as an instructional objective or specified it as a goal (Lederman, 1998). Abd–El-Khalick, Ball and Lederman, (1998), and Wright
(1989), assert that teachers rarely consider the nature of science when planning for instruction or making instructional decisions.

Understanding of the nature of science has been described as being central to the achievement of scientific literacy (Clough, 1995). Indeed, recent efforts to reform science education in the United States also strongly emphasise the understanding of the nature of science as an essential outcome and also an essential attribute of scientific literacy (AAAS, 1993; NRC, 1996). According to McComas, Clough and Almazroa (1998), a better understanding of the nature of science will enhance students' understanding of science's strengths and limitations, interest in science and science classes, social decision making and learning of science content. To be effective in teaching the nature of science, teachers must hold the belief that such is both important and understandable, and then design instruction deliberately to achieve it. While science teachers should strive to provide students with experiences in scientific inquiry, they should also make them understand the nature of science through explicit classroom discussions and reflections about the nature of inquiry (Lederman, 1992).

Researchers and science educators are increasingly arguing that for teachers to make meaningful changes in their instructional practices, they must become more reflective in their teaching practices in ways that make their knowledge and beliefs about pedagogy, their students and the nature of their discipline more explicit, and they must be more willing to reconsider their practices on the basis of these reflections (Clift, Houston, & Pugach, 1990; Schon, 1991).

Science teachers' beliefs about the nature of science are central to the achievement of scientific literacy (NRC, 1996). Any misunderstanding that both students and teachers hold regarding the nature of science will affect students' attitude towards science and science teaching, and that clearly has an impact on student learning (Tobias, 1990). Teachers' beliefs about their students are discussed in the next section.

**Beliefs about their Students**

The assumptions that teachers make about their students and how their students learn are likely to influence how they approach their teaching tasks and how they interact with their students. Anning (1988) found that teachers of young children held various
beliefs and theories about children's learning that influenced how they structured tasks and how they interpreted information about the children. The teachers' conception of children's learning focus on the importance of active involvement, for example or on the need for an emotionally secure environment in which failure is non-threatening, or on the value of exploration in open-ended activities where learning is through trial and error (Anning, 1988).

Teachers with different beliefs about children's learning tend to provide different types of classroom activities and support different patterns of classroom interactions. Experimental studies of teacher attributes have suggested that various features of students influence teachers' judgements of students and their behaviour towards them (Levine & Wang, 1983). Such features include the efforts that students appear to put into their studies (Peterson & Barger, 1984), their personal characteristics (Rohrkemper & Brophy, 1983), and even their attractiveness (Ritts, Patterson & Tubbs, 1992).

Beliefs about Cultural Issues in Science Teaching

Social constructivism characterises the nature of learning to include the following:

- knowledge is not a passive commodity to be transferred from the teacher to learners;
- learners cannot and should not be made to absorb knowledge in a sponge-like fashion;
- knowledge cannot exist separately from the knower;
- learning is a social process mediated by the learner's environment; and,
- the prior or indigenous knowledge of the learner is of significance in accomplishing the construction of meaning (Jegede, 1995; Von Glassersfeld, 1990).

All learning takes place in a social context. The role of the social context is to scaffold the learner, provide hints and help to foster co-construction of knowledge while interacting with other members of the society (Linn & Burbules, 1993). Contemporary literature has shown that recognising the social context of learning, as well as the effect of the learner's socio-cultural background in the teaching and learning of science, is of primary importance for successful learning in science (Cobern, 1994; Jegede, 1995).
Cobern (1993) asserts that students' views are grounded in a cultural milieu and students' culture influences significantly their construction of meaning. Teachers must not suppose that cultural identification is limited to such conspicuous group identifiers as race, language or ethnicity (Schatzman & Strauss, 1996). Other significant factors that influence students' construction of meaning and also form part of their cultural identity, include economic and education levels, occupation, geographic location, gender, religion and philosophy (Schatzman & Strauss, 1996).

A student constructs knowledge so that the knowledge is meaningful in the student's life situation. Contextual constructivism carried to its logical conclusion compels the investigation of students' views within cultural context, which gives meaning to those views. Writing about the difference between students' traditional culture and the culture of western science, Ogawa (1989) states:

Science, the product of western modernisation, should be taught in the context of a foreign culture in school science in a non-western society. On the basis of this position, science teachers need not only know western science itself but also to be aware of the traditional and scientific ways of thinking, and views of nature (p. 47).

Findings by Jegede et al. (1989) indicate that there are five indicators of socio-cultural influences on the learning and teaching of science in Nigeria. These include authoritarianism, goal structure, traditional worldview, societal expectation and sacredness of science.

Authoritarianism refers to a traditional society where only the elders exert authority in decision-making. Such locus of authority is sometimes transferred into the classroom where the teacher is seen as the elder who knows all about science. Goal structure refers to people's interaction pattern that is predominantly cooperative in nature and everyone works towards the same goal. This contrasts with an individualistic competitive orientation that school science portrays to students. Traditional worldview refers to the African people's strong beliefs in supernatural forces. This creates conflicts when the learner's scientific knowledge is not in agreement with his/her traditional worldview. Societal expectation refers to a common situation where a student views his/her
achievement in school as a reflection of home, friends and community. This is because the behaviour of any member in the community is linked to and governed by the behaviour of the larger community. Sacredness of science on the other hand refers to the pervasive view held by a large proportion of Africans that the study of science is special in that it requires magical explanations (Jegede et al., 1989). They concluded that: (i) any Western science curriculum in a non-western environment which does not take particular consideration of the traditional worldview of the learner risks destroying the framework through which concepts are likely to be interpreted, (ii) a student might perform excellently in a western science classroom without assimilating significantly any scientific knowledge or being enthusiastic about displaying the associated values and attitudes. The good scientist at school, can at home, be a ‘traditionalist’ without any feeling of cognitive perturbation or dissonance (Jegede et al., 1989).

It is important for science teachers to understand the fundamental, culturally based beliefs about the world that students bring to the class, and how these beliefs are supported by students' cultures (Cobern, 1993) because science education is successful only to the extent that science can find a niche in the cognitive and socio-cultural milieu of students (Jegede & Okebukola, 1993). The learner's worldview is grounded in his or her cultural setting and acts as a framework within which the constructed knowledge of science concepts are assimilated. Science teachers should ensure that learning begins from where the learner is, what he or she already knows, and takes account of the social and cultural context and the needs of the learner. As the teacher develops more understanding of the cultural context, he/she begins to incorporate other beliefs into his/her existing belief structure. Ultimately, the incorporation and addition of beliefs may lead him/her to alter his/her original beliefs about the students, about the context or even about teaching with a subsequent influence on his/her classroom practice.

Science Teachers' Pedagogical Content Knowledge

This fourth and last part of this review considers the nature of pedagogical content knowledge and the relationship between science teachers' pedagogical content knowledge and teaching behaviour.
The Nature of Pedagogical Content Knowledge

Literature from reform initiatives such as the Holmes Group (1986) and the Renaissance Group (1989) and the recently developed United State's National Science Education Standards (NRC, 1996) and the Benchmarks for Science literacy (AAAS, 1993), have further emphasised the importance of subject matter knowledge in science teaching and learning. These documents contain not only key subject matter concepts for students' learning, but they also inform pedagogical issues related to pedagogical content knowledge. Indeed, it has become clear that both teachers' pedagogical knowledge and teachers' subject matter knowledge are crucial to good science teaching and student understanding (Buchmann, 1982; Tobin & Garnett, 1988).

The concept of pedagogical content knowledge was originally suggested as a third major component of teaching expertise by Lee Shulman (1986) and his colleagues (Carlsen, 1987; Grossman, Wilson & Shulman, 1989; Mark, 1990). The idea represents a new and broader perspective in the understanding of science teaching and learning. Pedagogical content knowledge is a type of knowledge that is unique to teachers, and is based on the manner in which teachers relate their pedagogical knowledge (what they know about teaching) to their subject matter knowledge (what they know about what they teach). It is the integration or synthesis of teachers' pedagogical knowledge and their subject matter knowledge that comprises pedagogical content knowledge. According to Shulman (1986):

Pedagogical content knowledge embodies the aspects of content most germane to its teachability. Within the category of pedagogical content knowledge I include, for the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations; in a word, the ways of representing and formulating the subject that make it comprehensible to others...It also includes an understanding of what makes the learning of specific concepts easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning (p. 9).
In a latter article, Shulman included PCK in what he called “the knowledge base for teaching”. This knowledge base consists of seven categories, three of which are content related (i.e. content knowledge, PCK and curriculum knowledge.) The other four categories refer to general pedagogy, learners and their characteristics, educational context and educational purposes (Shulman 1987). The key elements in Shulman’s conception of PCK are knowledge of representations of subject matter on the one hand and understanding of specific learning difficulties and student conceptions on the other (van Driel et al., 1998). Teachers may derive and develop their PCK from their understandings of content, and their own school experience (Shulman, 1987).

Even though other scholars seem to adopt the two key elements of PCK in Shulman’s conception (i.e., knowledge of comprehensible representations of subject matter and understanding of content related learning difficulties); each of them has extended the concept by including in PCK some other categories or aspects of knowledge. For example, Grossman (1990) perceived PCK as consisting of knowledge of strategies and representations for teaching particular topics and knowledge of students’ understanding, conceptions, and misconceptions of these topics. In addition, PCK is composed of knowledge and beliefs about the purposes for teaching particular topics and knowledge of curriculum materials available for teaching. Grossman asserts that teachers can derive and develop their PCK from observation of classes, both as a student and as a student teacher, disciplinary education, specific courses during teacher education, and classroom teaching experience.

Mark (1990) also broadened Shulman’s model by including in PCK, knowledge of subject matter and knowledge of media for instruction. Cochran, DeRuijter and King (1993) in their revision of the Shulman’s original model of PCK assert that their own version is more consistent with a constructivist perspective of teaching and learning. They describe PCK as pedagogical content knowing. They conceptualise PCK much broader than Shulman’s view. They defined PCK as a teacher’s integrated understanding of four components of pedagogy, subject matter content, student characteristics and the environmental context of learning (Cochran et al., 1993, p. 266). This model of PCK not only includes subject matter knowledge and specific pedagogical knowledge but also teachers’ understanding of students’ characteristics and knowledge of the environmental context of learning. Teacher’s understanding of student’s characteristics includes student abilities, and learning strategies,
developmental levels, attitudes, motivations and prior conceptions. Context includes teacher's understanding of the social, cultural and physical environment. Their model that views teachers' PCK as an integrated understanding of the four components of teachers' knowledge outlined above is summarised in Figure 1.

Figure 1. A model of pedagogical content knowledge (PCK) derived from Cochran et al. 's (1993) model.

Cochran, King and DeRuiter (1991) also used Venn diagrams to show how the four components or domains of teacher knowledge overlap and how PCK is centralised within the overlaps. The diagram also shows that greater overlap symbolises increased integration of the four components and thus greater PCK development.

The idea of integration of knowledge components is also central in the conceptualisation of PCK by Balboa & Stiehl (1995). They identified five components of PCK which include: knowledge of subject matter, knowledge of students, knowledge of instructional strategies, knowledge of teaching/learning context and one's purposes
for teaching. Carlsen (1999) asserts, "PCK is a form of teacher knowledge, distinct from other forms and defined by its relationship to those forms" (p. 135). He described teacher's knowledge as consisting five general domains: PCK, subject matter knowledge, general pedagogical knowledge, knowledge about specific educational context and knowledge about general educational context.

While some scholars hold the integrative view of PCK, others believe in the transformative model. The transformative model describes PCK as resulting from the transformation of different forms of teacher knowledge bases (e.g. Magnusson, Krajcik & Borko, 1999). PCK in Shulman's conception implies a transformation of subject matter knowledge, so that it can be used effectively and flexibly in the classroom teaching process. Shulman's (1986) explains that what is unique in PCK is that it requires teachers to transform their subject matter knowledge for the purpose of teaching. This transformation occurs as the teacher reflects and interprets the subject matter, finds multiple ways to present the information as analogies, metaphors and examples, adapts the materials to the developmental levels and abilities of the students and finally tailors it to those specific individuals or group of students to whom the information will be taught (Shulman, 1986). Gudmundsdottir (1987) describes the transformation process as a continual restructuring of subject matter knowledge for the purpose of teaching.

Magnusson, Krajcik and Borko (1999), while arguing for uniqueness of PCK, take a strong stance on the existence of PCK as a separate domain of knowledge that is iteratively fuelled by its component parts: subject matter knowledge, pedagogical knowledge and knowledge of context. Gess-Newsome (1999) compares the transformative and the integrative models of PCK. She describes the transformative model of PCK as a transformation of subject matter knowledge, pedagogical knowledge and of contextual knowledge. She states that from the transformative perspective: "the PCK that helps students understand specific concept is the only knowledge used in classroom instruction" (p. 12). She explains: "while knowledge bases containing subject matter, pedagogy and context exist; they are latent resources in and of themselves and are only useful when transformed into PCK" (p. 12). This view is that knowledge of subject matter, pedagogy and context are transformed into PCK, which is the knowledge base used for teaching. Teachers therefore, can justify their practices and decisions within the domain of PCK. An effective teacher in relation to this model is
one who has a well formed PCK for the science concepts that are commonly taught by him/her. Gess-Newsome also describes the integrative model of PCK as one "in which the teacher's task is to selectively draw upon the knowledge bases of subject matter, pedagogy and context and integrate them as needed for effective learning opportunities" (p. 11).

The preceding discussion is by no means exhaustive; it has only tried to demonstrate that there is no universally accepted conceptualisation of PCK. Between scholars, differences occur with respect to the elements they include or integrate in PCK, and with respect to specific descriptions of these elements. Yet, scholars seem to agree that PCK differs from knowledge of general pedagogy, of educational purposes, and of learner characteristics in a general sense (Van Driel et al., 1998). They seem also to agree that though it is difficult to separate PCK from content knowledge, it appears as though a thorough and coherent understanding of content is necessary for effective PCK (Van Driel et al., 1998). Moreover, scholars seem to agree with the notion that PCK is developed through an integrative process rooted in classroom practices, implying that experienced teachers have higher level of PCK at their disposal.

Gess-Newsome (1999) describes the continuum that exists between the integrative and transformative models of PCK and concludes that most authors position themselves between the two extremes; asserting that such positions "recognise both the fundamental knowledge bases of subject matter, pedagogy and context and their reciprocal and nurturing relationship with PCK" (p. 13). PCK then can be regarded as an important domain of teachers' knowledge that does not totally subsume other aspects of knowledge.

The position of this author lies within the continuum and particularly favours the integrative idea as presented in the Cochran et al.'s (1993) model. This position recognises that integrated understanding of the fundamental domains of teacher knowledge: knowledge of subject matter, pedagogy, knowledge of student learning and knowledge of context would help generate and develop teachers' PCK. Changes in teachers PCK could also inform further developments in teacher knowledge domains. For example, contextual factors have been shown to lead to the creation of new PCK and new PCK (such as the capacity to see insights in students' ideas) may stimulate the teacher to understand students differently and to re-create the classroom setting or to
change the context of instruction (Carlson, 1999). The advantage of this position is that knowledge integrated to teach a particular lesson can continuously be reflected upon, deconstructed into their parent domains, reorganised or further integrated (Gess-Newsome, 1999). This may lead to further understanding of the knowledge domains with the consequence of further development of teacher’s PCK.

This researcher acknowledges the different usage of the word integrate by both Cochran et al. and Gess-Newsome. For the remainder of this thesis the use of Cochran et al.’s expression is adopted. That is, the use of the term integration is meant in the same way that Cochran et al. used it and not intended to fit within the Gess-Newsome’s categorisation.

The author’s integrative position is also consistent with the on-going efforts in his college of education to integrate, by design, all courses in education, major sciences and other related courses in their teacher preparation efforts so as to improve teachers’ classroom practices. How PCK relates to effective science teaching and learning is discussed in the next section.

**Relationship between PCK and Teaching Behaviour**

Lee Shulman (1987) developed the construct of pedagogical content knowledge (PCK) in response to some of the problems of teaching and teacher education. This important addition to thinking about teaching is recognised in the content section of America’s National Science Teachers Association standards (NSTA, 1998). The NSTA’s pedagogy standards also suggest that science teachers should know about organisation of classroom experiences (NSTA, 1998). However, to be able to effect such ‘organization’ requires a deep understanding of content and pedagogy. The fact that science teachers must have adequate content preparation, a substantial part of which usually takes place outside of the colleges of education in Nigeria, presents problems for pre-service teachers and science teacher educators.

The NSTA Standards accurately identify some of these problems when the authors state:

There is a poor match between learner needs and teaching methodology.... In many of these traditionally taught courses the
emphasis is on learning large amounts of information at a rapid pace and this division of knowledge, for convenience into disciplines, fields and sub-fields that may contain the development of linkages among concepts across fields (NSTA, 1998, p. 5).

Most science teacher content knowledge comes from disciplinary fields, while understanding of teaching comes from the field of education. This separation reveals the problem referred to above and reinforces a model of scientific discipline that differs from models of teaching and learning science.

Several studies have examined the practical connection of PCK to science teaching. A recent study by van Driel, Valoop and de Vos (1998) found changes in teachers’ classroom behaviours as a result of developing pedagogical content knowledge. They found, through empirical study, that there might be value to having prospective teachers study subject matter from a teaching perspective. Vonk (1984) after studying the problems of beginning teachers, concluded:

Many problems originate from the fact that beginners have too little pedagogical content knowledge, they lack an overview, which makes classroom teaching so complex; that problem of classroom discipline and classroom management is inevitable... have perspective of their role as a teacher, which is too optimistic and are not prepared for meeting and dealing with unmotivated students (p. 5).

Other studies have also shown that new teachers have incomplete or superficial levels of PCK (Carpenter, Fenneman, Peterson & Carey, 1988; Feiman-Nemser & Parker, 1990). A novice teacher tends to rely on unmodified subject knowledge (most often directly extracted from the curriculum or texts) and may not have a coherent framework or perspective from which to present the information. The novice teacher also tends to make broad pedagogical decisions without assessing students’ prior knowledge, ability levels, or learning strategies (Carpenter et al., 1988). In addition, pre-service teachers have been shown to find it difficult to articulate the relationships between pedagogical ideas and subject matter concepts (Gess-Newsome & Lederman, 1993); and low levels of PCK have been found to be related to frequent use of factual and simple recall questions (Carlsen, 1987).
These attitudes also indicate that new teachers have major concerns about PCK, and they struggle with how to represent the concepts and ideas in ways that make sense to the specific students they are teaching (Wilson, Shulman & Richert, 1987). Grossman (1990) shows that this concern is present even in new teachers who possess the substantial subject matter knowledge gained through a masters degree in a specific subject matter area, and Wilson (1992) documents that more experienced teachers have a better overarching view of the content field and pedagogical knowledge on which to base teaching decisions.

Science teachers can increase their level of PCK if they begin to more often reflect on or think about why they teach specific ideas the way they do and begin to think about the following types of questions. Which ideas need most explanation? Why are those ideas more difficult for the students? What examples, demonstrations, and analogies seem to work the best? Why did they work or not work? Which students did they work for best?

Contemporary research has focused on how to describe teachers' PCK and how it influences the teaching process. We have yet, however, to fully understand how components or attributes of PCK reflect in science teachers' classroom practice and how they really develop. There are ongoing research efforts also to fully understand how to enhance pedagogical content knowledge in pre-service and in-service teacher education programs. Components or attributes of PCK exhibited by science teachers and how they influence classroom practice, among other things, have been examined in this investigation.

**Summary and Conceptual Framework**

Evidence from the various studies cited in this literature review indicates, among other things, that the development of a nation depends in part on its level of science education. Science education empowers individuals and maximises national intellectual resources in order to sustain social and economic progress. This is perhaps the reason why many countries of the world have gone through circles of curricular reforms in science education in order to attain rapid development in science and technology. In the
United States of America, the U.K, and in Australia, for example, attainment of scientific literacy is regarded as a general goal of science education in the compulsory years of schooling. In Canada, science education is regarded as central to acquisition of appropriate skills for technological development and science is seen as a 'way of knowing.' Among African countries science education is being given high priority in their educational policies, and scientific literacy is seen as central to their technological growth and development.

Central to the achievement of scientific literacy is to have effective science teaching and active engagement of students in learning science. Students develop new knowledge through a process of teaching and learning in which the learner uses existing knowledge to actively construct meaning from new experiences.

Studies reveal that the beliefs that individuals hold are the best indicators of the decisions that they make in the course of everyday life. Teachers' beliefs have been found to be situation-specific and action oriented. The following classes of teachers' beliefs affect their classroom actions and should be examined in a comprehensive model of teaching:

- beliefs about the nature of subject matter,
- beliefs about the nature of learning process, both cognitive and affective,
- beliefs about the nature of teaching process and the role of the various kinds of instruction, and
- beliefs about individual learners and classes of learners.

Effective science teaching practices are grounded in teachers' beliefs and their knowledge about science teaching.

PCK has been described as a set of special attributes that helped someone to transfer knowledge of content to others (Geddis, 1993). Shulman (1987) stated that PCK included those special attributes a teacher possessed that helped him/her guide students to understand content in a manner that was personally meaningful. While some scholars hold the transformative view of PCK others hold the integrative view. Gess-Newsome (1999) claims that the view of many scholars is that which "recognises the fundamental bases of subject matter, pedagogy and context and their reciprocal and nurturing relationship with PCK" (p. 13).
Classroom management and control are important issues in science teachers' classroom behaviour. Grossman (1990) contends that "classroom management and instruction are eternally married" (p. 6) and how teachers manage their classrooms enables or constrains the possibilities of effective teaching, classroom discourse, and student learning. Effective classroom behaviour no doubt, brings about effective teaching and active learning (Doyle, 1986). A broad continuum does exist between two extreme approaches to science teaching – transmissive teaching and constructivist teaching (Dawson, 1997). Transmissive teaching has the aim of transmitting a body of important scientific knowledge to the students. To do this, teacher-centred methods are used – lecturing, teacher-centred class discussions, giving notes, using structured laboratory exercises and standard problems from the textbook.

The constructivist teacher has the aim of ensuring that the students learn and understand a body of knowledge and students themselves must be fully involved in constructing knowledge, not simply receiving it ready made. Students are therefore made to think carefully about each step of the learning process. They are required to try to generate new ideas; to identify what needs to be explained; to suggest hypotheses and suitable tests for these; to criticise results and inferences and to search for alternatives; and to identify and summarise relationships between ideas and concepts.

The key to constructivist science teaching is the mental engagement of the students (Dawson, 1997). Findings from studies indicate that few teachers operate totally in accordance with the extreme transmissive model, fewer still are totally constructivist while most are somewhere in between. Many science teachers are said to lean towards the transmissive end of the scale (Dawson 1997; Yager 1991).

There is a growing amount of literature that suggests that the beliefs that teachers hold impact on both their perceptions and judgements, and that these in turn affect their behaviour in the classroom. Beliefs are assumed to be the best indicators of why individuals make certain decisions. Teachers' beliefs act as referents for actions, and can be interpreted as what and why a teacher accomplishes a goal (Tobin, Tippin & Gallard, 1994). Beliefs of a teacher are grounded in experience. Those beliefs that have proved to be viable in the sense that they have enabled him/her to achieve goals are used as a guide for actions and those that are not viable in certain contexts are not used as
referents for actions. Beliefs about teaching, learning, and learners and about the subject are often strongly held and difficult to change. How teachers feel about a whole range of issues relating to teaching and learning will consciously or unconsciously affect their choice of priorities and shape what they do.

Shulman, (1986) introduced the construct of PCK to describe the professional knowledge of teachers. The science teacher does not only need to know the subject matter, he/she also needs to know the order in which topics should be presented, what demonstration to employ, what question to ask, how to respond to specific students' responses, how to assess what students learn and how to apply the concept to the world outside. PCK is involved in knowing what knowledge is relevant, in restructuring the knowledge, and in representing the knowledge in ways that effectively mediate learning of all students in the class (Tobin & McRobbie, 1999).

Many scholars have listed attributes or components of PCK. Veal and MaKinster (1999) assert that the PCK components bear relationship and connection among them that suggest useful ideas for teaching. Smith and Neale (1989) describe PCK as having three components: Knowledge of typical student errors, knowledge of particular teaching strategies and knowledge of content elaboration. They believed that the integration of these components was vital to effective science teaching. Similarly, Cochran, King and DeRuiter (1991) defined PCK as “the way in which teachers relate their pedagogical knowledge to their subject matter knowledge in a school context, for the teaching of specific students” (p.1). This definition incorporated four components: knowledge of subject matter, knowledge of students, knowledge of environmental context and knowledge of pedagogy. Magnusson et al. (1999) also conceptualised PCK for science teaching as consisting of five components: orientation towards science teaching, science curriculum knowledge, knowledge of student understanding of specific science topics, knowledge of assessment and knowledge of instructional strategies.

The most common and recurring components or attributes of PCK from these models are the knowledge of subject matter, knowledge of student learning, knowledge of context and knowledge of pedagogy (Veal & MaKinster, 1999). This reinforces the Cochran et al.’s (1993) model of PCK that is also adopted in this study. The central location of PCK signifies its importance; the surrounding components or attributes are all connected, representing an integrated nature of the components.
Thus PCK involves knowledge of subject matter, knowledge about students and how they learn, knowledge of general pedagogy and knowledge of context. These fundamental knowledge domains bear a "reciprocal and nurturing relationship with PCK (Gess-Newsome, 1999). Figure 2 presents PCK as a core surrounded by the teacher knowledge domains to illustrate this relationship. Integrative understanding of these knowledge domains is capable of generating or developing teacher's PCK and changes in PCK can inform further development of knowledge in any of the teacher knowledge domains. One of the critical assumptions underlying the construct of PCK that has influenced research is that teacher's knowledge and beliefs influence classroom practice (Baxter & Lederman, 1999). Veal (1998) asserts that teachers' beliefs and PCK are inextricably intertwined and that the relationship between them is synergistic and creates a unified understanding of their practice. Teachers' beliefs inform their choice of content knowledge or strategies, which in turn, influence the pedagogical content knowledge they deploy. Teachers' classroom practice or knowledge gained in the classroom or through in-service training informs their PCK (Carlson, 1999). Both beliefs and PCK therefore determine classroom behaviour while experiences gained in the classroom practice also influence both teachers' beliefs and PCK.

A report by the OECD (2002) indicates that teachers often face the most significant constraints to effective teaching and innovations in the lower secondary schools. Most of the school constraints are hinged on funding (Bajah, 1997). Budget constraint is a common phenomenon in secondary schools, particularly in Sub-Saharan Africa and this limits the availability of facilities, textbooks and laboratories. Research (Okebukola, 1995, Bajah, 1997) indicates that secondary science teachers in Nigeria teach under the constraints of large classes, shortages of facilities and personnel, heavy teaching loads, and lack of motivation. These factors have the capacity to limit effective science teaching since they impact on teachers' beliefs and classroom practices.

Science teachers' classroom behaviour has a direct impact on students' learning behaviour and on learning outcomes. This conceptual framework of teachers' beliefs and PCK, constraints and classroom behaviour has been used in conceptualising the design of this investigation.
Teachers' beliefs about science effective science teaching
- Epistemology
- Nature of science
- Science teaching
- Student learning
- Environment
- Content

Constraints:
Class size, facilities, teaching loads, motivation of teachers and students etc

Figure 2. The conceptual framework
CHAPTER 3: METHODOLOGY

Introduction

This Chapter describes the research methods and procedures that were applied in this study which was set in the Lagos State of Nigeria. The primary purpose of the study was to investigate Nigerian secondary school teachers’ beliefs about effective science teaching and their pedagogical content knowledge, and how these influence their classroom teaching practices. The desire to undertake this investigation arises from the Researcher’s curiosity and involvement in science teaching and science teacher education at the College of Education in Lagos State of Nigeria.

This Chapter is structured into five sections. In section one, the research design underpinning the study and the rationale for adopting both quantitative and qualitative (interpretive) approaches are presented. Section two focuses on the target population, the sample and the sampling method. Section three describes the data gathering techniques and instruments employed in the study. The procedures of data collection and ethical considerations for the study are presented in section four, and section five describes the methods of data analysis.

Research Design

This study was designed to obtain appropriate data by interacting with the science teachers through survey questionnaires, interviews, document analysis and classroom observation sessions, so as to be able to describe, analyse and interpret their beliefs about science teaching effectiveness, their pedagogical content knowledge, how they teach, and their reflections about their teaching. The study employed a mixed methods approach comprising both descriptive and interpretive methods. The first part of the study involved a descriptive approach employing a survey questionnaire designed to seek information on the teachers’ practices, and beliefs.

The second part of the study involved an interpretive approach involving the compilation of in-depth case studies of selected teachers through interviews, observation and analysis of documents. The interviews elicited information from the teachers about their experiences, opinions and beliefs. Lesson observations provided detailed descriptions of their teaching activities, behaviours, actions and the full range of interpersonal interactions and organisational processes that are observable.
Information from the document analysis on the other hand, included excerpts, quotations or entire passages from different forms of written records including the Integrated Science curriculum document, scheme of work for Integrated Science, teachers’ diaries and lesson notes, all of which are considered relevant to this investigation. The use of case studies was considered to be particularly relevant because teaching is maintained by interactions, where all elements in the social setting (school in this case) are interactive and simultaneously affect each other (Patton, 1990). The study employed these multiple methods in order to gain understanding of the teachers’ beliefs and PCK.

Data from these sources were used to infer a general profile of the science teachers’ PCK (Baxter & Lederman, 1999). Cochran et al.’s (1993) four contributing components of PCK (knowledge of content, knowledge of general pedagogy, knowledge of student learning and knowledge of context) informed data representation and interpretation in this study. Since the science teachers teach integrated science at the junior secondary level, the study focused more on their general PCK. Veal (1998) explains that the general PCK illustrates those teaching methods specific to subject areas such as science. He found out that the general PCK developed more “when participants were placed in an integrated science classroom since they were unable to experience teaching all topics in subject domains like chemistry or physics” (Veal, 1998, p. 7).

Data from interview, observations and written documents were interpreted by the Researcher to make sense of the classroom events and processes. To enhance the credibility and trustworthiness of the study’s findings, the research design provides opportunities for triangulation of data.

The Researcher

The Researcher has previous science education research experience and more than 10 years of experience of science teaching and teacher preparation at a College of Education, and has masters degrees in science and curriculum studies. This makes him a credible interpreter of the data collected.

Population and Sample

Lagos State is one of the 36 states in the Federal Republic of Nigeria and is the most populous state with an estimated population of about 10 million people (National Population Commission of Nigeria, 1998). The State is divided into 20 Local Education...
Districts (LED) which are responsible to the State Ministry of Education. The Ministry oversees the administration and management of primary, secondary and technical schools within the State. The sample for this investigation was drawn from two of the 20 Local Education Districts in the State. They were the Ojo and Amuwo Local Education Districts (LEDs).

All of the 30 secondary schools in the two LEDs were involved in the study. The choice of the secondary schools in these two LEDs was contingent upon their proximity to each other and to the Researcher’s base and the existence of the ‘school village’ concept, where two or more schools are located in clusters in the same area. These 30 secondary schools of the two LEDs were considered to be representative of the secondary schools in the State because they all use and depend on the State’s Integrated Science Curriculum for junior secondary science, and are under the administrative control and supervision of the same State Ministry of Education. The two local education districts involved in the study have more secondary schools than most other districts in the Lagos Metropolis.

All 70 science teachers involved in the teaching of Integrated Science at the junior secondary school level in the 30 secondary schools were surveyed. Of the 70 science teachers 65 completed and returned questionnaires, which represents a 93% return rate in the first part of the study. Furthermore, the number represents an average of about two Integrated Science teachers per school. The number was regarded as reasonably manageable given the nature of the questionnaire, which included many open response items.

The sample for case studies in the second part of the study comprised three science teachers, who were selected by purposive sampling from the total number of the science teachers that completed and returned questionnaires in the first part of the study. The logic and power of the purposive sampling method lies in selecting information-rich cases for in-depth study. Patton (1990) asserts that “information-rich cases are those from which one can learn a great deal about issues of central importance to the purpose of the research, thus the term purposive sampling” (p. 169). Information derived from preliminary analysis of the survey data informed the selection of the case study teachers. Factors such as years of teaching experience, qualifications, school location, gender, knowledge and understanding of the purpose of the study, as well as consent and
approval to take part in further investigations were taken into consideration during the
selection of the case study teachers.

Research Instruments

Survey Questionnaire

The purpose of a survey questionnaire is to elicit information about the characteristics
or opinions of its respondents (May, 1993). The obvious limitation of the questionnaire
is that it only enables researchers to obtain information concerning what people say they
do, believe, like or dislike. In this investigation, the use of a survey questionnaire was
complemented by the use of case studies, which provided some corroboration of claims
made in the questionnaire. The questionnaire focused on science teachers' beliefs about
effective science teaching, about effective teaching styles, about themselves and their
roles as teachers, about their schools, about the nature of science and science teaching,
and about their students' learning. In the development of the questionnaire, particular
attention was given to the need to maintain clarity, unambiguity, lack of bias, relevance,
and to be succinct and avoid vagueness.

The teachers' questionnaire (Appendix A) consisted of five sections. The first section
comprised questions designed to elicit demographic information regarding the teachers' 
school, age, qualifications, years of experience, gender, subjects taught and major
subject areas. The second section focused on teachers' beliefs and ideas about effective
science teaching, current practices and teaching styles, student assessment methods, and
factors which inhibit their own effectiveness in science teaching. The third and fourth
sections focused on epistemological and pedagogical beliefs in science. These include
beliefs about the nature of science, science teaching and how students' learn. Section
five focused on teachers' beliefs and ideas about curriculum resources and the Lagos
State Integrated Science curriculum.

Case Studies

Three teachers were selected for case studies after a preliminary analysis of the survey
data and their selection was based on identifying information-rich cases.
Interviews

The purpose of the initial interview was to gather data concerning the case study teachers' views about effective science teaching, best practices in science teaching, their current ideas regarding the nature of science and science teaching, how students learn science, and current teaching and learning practices. The semi-structured interview focused on the following questions:

- What do you believe are the characteristics of effective science teaching and learning?

- To what extent do you believe science teaching (your teaching) in your school is effective? What do you do well? What aspects need improving?

- What are your views regarding the characteristics (nature) of science? How would you want your students to regard science? Why do you think it is taught in the school?

- Outline the three most important factors that inhibit effective science teaching and learning in your school? How do you think they can be addressed?

- How do your students prefer to learn science?

- How do you assess your students? What aspects of learning do you assess and what methods do you use?

An interview guide was developed and tailored to the context in which the interviewee operated (Appendix B). The interviews took place in the science teachers' schools and were audio-recorded. Each interview session was opened with an explanation of the purposes of the interview and the questions were adequately explained to remove any elements of ambiguity or misinterpretation on the part of the interviewees. Follow-up interviews were used throughout the case studies to probe aspects of teaching that were observed by the Researcher. The Researcher made efforts to ensure that a cordial interactive atmosphere existed throughout the course of the interviews in order to ensure credibility of the data collected.
Classroom observations

The three case study teachers who were interviewed were also observed as they taught science lessons in their schools. The focus at this stage of the study was to observe aspects of the teachers' teaching behaviour that were relevant to the research questions. Specifically, the teachers' teaching strategies, how they organised, interpreted and presented the content to the learners, their use of instructional materials and resources. Observations were recorded on a lesson observation sheet (See Appendix C).

Each teacher was observed five times. Each observation session was followed with an informal interview and discussions in a friendly and relaxed atmosphere regarding emerging issues to try to understand the factors influencing the teachers' practices. The teachers were encouraged to use their lesson plans to guide their reflections and identify those aspects of the lesson, which they believed had gone particularly well and their reasons for adopting particular strategies and to comment on other aspects they needed to modify in subsequent lessons. The classroom observations were needed in order to gain an understanding of the science teachers' PCK in relation to how they translate or integrate their understanding into classroom practice and to be able to describe the attributes or components (Veal, 1998) of PCK that manifest in the teachers' classroom practices.

Furthermore, the focus on teachers' PCK in relation to teachers' understanding of particular knowledge domains or attributes (Veal, 1998) of subject matter knowledge, knowledge of student learning, knowledge of general pedagogy and knowledge of context is by design. First, it is consistent with the integrated model of PCK that is adopted in this study. Second, a teacher's understandings of these domains are themselves components or attributes of his/her PCK (Veal, 1998; Baxter & Lederman, 1999) and are more easily recognisable or measurable than, for instance the teachers' decision-making aspect of PCK (Baxter & Lederman, 1999). Even though, Baxter et al. (1999) advocate that PCK research should try to consider all aspects of PCK, this Researcher is of the view that the focus in this study provided adequate information about the teachers' understanding of their knowledge domains and how such understandings were organised or integrated.

Moreover, the Researcher's focus on the science teachers' PCK in relation to their understandings of these knowledge domains or PCK attributes is also consistent with the ongoing efforts in his college of education in Nigeria which are aimed at integrating.
by design, courses in education, sciences and other related disciplines in order to improve science teachers’ classroom practice.

Document analysis

To gain more understanding of the science teachers’ teaching practices, the Researcher examined (and made photocopies of) certain school documents, which were kept by the teachers for teaching activities. These included lesson plans, teachers’ diaries, schemes of work, and continuous assessment records. The Lagos State’s Integrated Science curriculum document was also examined with the view to gain more understanding of the structure of the content and other curricular materials recommended by the State.

Trustworthiness of the Instruments

An instrument is considered valid when there is confidence that it measures what it is intended to measure (Punch, 1998). In determining the validity of the survey questionnaire the Researcher presented it to a group of two experts in the field of science education to assess the questions for face and content validity. Moreover, the questionnaire was pilot tested using five science teachers (not among those involved in this study) who were also involved in teaching junior secondary science to determine the clarity and relevance of the questions in eliciting information on teachers’ beliefs and ideas about factors relating to effective science teaching and learning. The teachers involved in the pilot testing had similar characteristics to the target group and were selected from three schools from other two neighbouring Local Education Districts.

Lincoln and Guba (1985) suggest that credibility rather than internal validity be the criterion against which the truth-value of qualitative research be measured. If the truth-value of qualitative research lies in a very supportive researcher–subject relationship (Sandelowski, 1986) then the credibility of this study is ensured as a cordial relationship between the Researcher and the case study teachers was maintained throughout the research. The case study involved the use of interviews, classroom observations and document analysis, and triangulation of these data was aimed to maximise the richness, quality and credibility of the collected data.
Procedure for Data Collection

This investigation began with a pilot study, which was preparatory to the main study. The study itself was divided into two phases comprising a survey of science teachers and then case studies of selected teachers.

Pilot Study

The pilot study helped to verify whether the questionnaire and interview instruments would function as expected with the type of subjects for which the investigation was intended (Thomas & Nelson, 1996). It also helped the Researcher to demonstrate whether he could use these instruments and procedures accurately and reliably. The pilot study was conducted using the survey questionnaire and the interview guide as tools. Five science teachers, whose consent were earlier sought by the Researcher, were selected from three secondary schools in two neighbouring Local Education Districts. Their selection was based on their involvement in the teaching of Integrated Science in the local secondary schools and considering their socio-cultural similarity with the subjects of this study. The five teachers completed and returned the survey questionnaires. After a period of 10 days, the questionnaire was re-administered and all five teachers completed and returned the survey. Responses were compared to determine if any questions were not answered consistently on both administrations. Analysis of the teachers' responses to open-ended questions indicated that they were well understood by the teachers and reliable.

The purpose of the pilot study was to determine the level of understanding and relevance of the questionnaire items and the interview guide in eliciting teachers' views on issues relating to effective science teaching and learning.

Two of the science teachers involved in the pilot study were used to practice the administration of the interview and their classes were also used to pilot the classroom observation sheet. The selection of these two was based on their willingness to participate, years of teaching experience, qualification and gender. They were interviewed separately using the interview guide; each lasting for about 30 minutes, and the interviews were audio-taped. Their lessons were also observed on two occasions each and appropriate notes were taken using the lesson observation sheet. Each observation session lasted for about 40 minutes and was followed with informal discussions regarding the teacher's chosen strategies, alternative approaches and other
pedagogical views. This provided the opportunity to adequately rehearse the interview and observation techniques.

The teachers' interview responses indicated that they adequately understood the questions and their respective views regarding effective science teaching and learning were similar to those expressed when they responded to the survey questionnaire. The pilot study was concluded during week four of the first term of the Lagos State's schools calendar that started in the second week of September 2001.

Main Study

This study was carried out in the Lagos State of Nigeria and involved all 70 science teachers of Integrated Science in the 30 Secondary Schools in two Local Education Districts of Ojo and Amuwo-Odofin. A letter was written to the Director of Education in the two Local Education Districts (LEDs) to seek approval to carry out this study in their schools. The letter briefly stated the purpose and significance of the study, and was accompanied with a copy of the research proposal. After obtaining the approval of the LEDs (Appendix D) the Researcher visited the secondary schools with the letter of approval to meet the Principals and inform them about the study and seek their assistance and approval for the participation of their Integrated Science teachers in the study.

Contacts were also made with the science teachers. The Researcher sought their consent to take part in the study (see Appendix E) and used the opportunity to brief them on the aims, nature and significance of the study, and assured them of the confidentiality and anonymity of both their participation and involvement of their school in the study. Those initial contacts were used by the Researcher to develop researcher-participant rapport and to assure them that the study would not be in anyway judgmental of their teaching practices. The essence of this type of approach was to ensure participants' cooperation and improve the quality of the data to be collected (Punch, 1998). Furthermore, a written informed consent form was given to each teacher for his/her perusal and to formalise his/her participation by signing the statement of disclosure and the informed consent form. This was regarded as a formal commitment to take part in the study whilst accepting that they could withdraw at any stage (Appendix F).
Survey of the science teachers

The first phase of the investigation began in week five of the first term (10/10/01) as soon as the pilot study was concluded. The Researcher delivered the survey questionnaires to the science teachers in their schools. Of the 70 teachers, 65 completed and returned questionnaires, which were collected personally by the Researcher five days after they were delivered. A preliminary analysis was carried out after the collection of the questionnaires, which informed the selection of the three science teachers that were involved in the case studies.

Case studies

The case studies began during week three of second term, which started from January 7, 2002, with individual interviews with each of the three science teachers. The interviews were based on the questions listed in the interview guide (Appendix B) and the English language was the medium of communication throughout the interview sessions. Each interview was conducted in a comfortable environment devoid of any disturbances within the teachers' schools and lasted for about 35 minutes. The interviews were audio taped.

Classroom observation of the case study teachers commenced in March 2002 during week eight of second term. Five observation sessions were conducted with each of the teachers. Each session was followed with informal discussions, in which the teacher was encouraged to reflect on aspects of his/her teaching to gain a better understanding of the motives behind certain actions taken or not taken by the teacher. This also provided opportunities for the Researcher to ask follow-up questions and obtain clarifications on emerging issues. The teachers were encouraged to comment on aspects of their practice they considered quite appropriate and aspects they thought needed to be strengthened, and why they preferred those strategies they adopted in their classroom practices.

Documents kept by the teachers were selected for analysis after each observation session. Documents, which the teachers were able to provide for analysis, included diaries, scheme of work, continuous assessment records and the Integrated Science curriculum document. The field investigation was concluded in week eight of the third term in June 2002.
Summary of Sources of Data

The various sources of data used to answer each of the research questions are summarised in Table 3.1.

Table 3.1

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</tbody>
</table>

Note: * Means research question.

Data Analysis

Presented in this section are methods of data analysis that were employed for the teachers’ survey, interview, and classroom observation and document analysis.

Questionnaire

Quantitative data from the teachers’ survey were analysed using descriptive statistical methods. The questionnaire included open-ended questions and items that required the teachers to respond on an agreement scale or on a frequency of occurrence scale. Responses to open-ended questions were coded into categories (see the coding manual, Appendix G). The number of responses in each category, and the percentage of teachers giving each category of response were calculated. The responses on the scale items were coded in relation to the scale so that the number and percentage that responded Strongly Agree, Agree, Neutral, Disagree and Strongly Disagree could be calculated.
Interview and Classroom Observation

Data from interviews, observations and document analysis were organised into different categories that express themes of meaning. All recorded interview sessions were transcribed (Appendix H) verbatim without any interpretation. In order to gain an understanding of the emerging themes in the data, the transcripts were read repeatedly, and coding and categorising the patterns in the data were adopted. For example, aspects of the science teachers' ideas and practices were ranked, categorised and interpreted on the basis of their pedagogical content knowledge. Data from the interview, observation and the document analysis were used to identify and record a profile of each teacher's teaching characteristics and classroom behaviour.

Case study descriptions were presented in narrative form with examples from the data to provide insight as to when and where in the data the idea emerged. Relevant quotes from the participants were also used to complement the data presentation. Evidence from the analysis of documents assisted in verifying the claims of the participants.

Limitations of the Study

The fact that PCK is both an internal and external construct that cannot be measured directly (Baxter & Lederman, 1999) is a limitation of this study. PCK has been inferred from a range of data sources including the survey, interviews and classroom observations. Furthermore, additional case studies may have provided a richer data and a wider range of perspectives for the investigation.

Summary of Chapter

The primary purpose of this study was to investigate Nigerian secondary school teachers' beliefs about science teaching effectiveness, their pedagogical content knowledge, and how these influence their classroom teaching practices.

The study employed a mixed method approach comprising both descriptive and interpretive methods. The first part involved a descriptive approach employing a questionnaire, which sought information on present teaching practices, beliefs, opinions and attitudes of the science teachers. The second part involved an interpretive approach
using case studies of three teachers through interviews, direct classroom observations and document analysis.

Two Local Education Districts of Lagos State – the Amuwo and Ojo LEDs were involved in the study. The entire population of Integrated Science teachers at the junior secondary level (N = 70), from the 30 secondary schools were surveyed. Three of the science teachers were selected for case studies.

Data collected were analysed both quantitatively and qualitatively. The quantitative analysis involved simple percentages and frequency distributions, means and standard deviations using the SPSS statistical program. Responses to open questions, views and opinions, were categorised and their frequencies determined. Audio-recorded interviews were transcribed, coded and categorised, and emerging themes identified. Triangulation of the data was used to ensure consistency and trustworthiness of data.
CHAPTER 4: QUESTIONNAIRE RESULTS

Introduction

This Chapter reports data from the survey questionnaire. The Chapter is divided into eight sections. The first section presents demographic data regarding the science teachers, while the second, third and fourth sections are respectively teachers' beliefs about the nature of science and science teaching, organisation of the science curriculum, and teaching and learning in science. Teachers' beliefs about the role of students are presented in the fifth section. Teachers' views about effectiveness of strategies and lessons, and factors that inhibit teaching effectiveness are presented in the sixth and seventh sections respectively. The last section provides a summary of the Chapter. Also presented at the end of each section are assertions derived from the major findings from the data analysis.

Demographic Data

The entire population of science teachers that are involved in science teaching at the junior secondary level at the 30 secondary schools in the two local education districts of Lagos State were surveyed. Of the 70 science teachers, 65 completed and returned questionnaires, which represents a 93% return rate. The sample of 65 science teachers included 30 males (46%) and 35 females (54%); with 40 (62%) teaching in urban schools and 25 (38%) located in rural schools. The respondents' ages, teaching qualification and years of teaching experience are summarised in Tables 4.1-4.4.
Table 4.1

<table>
<thead>
<tr>
<th>Age range</th>
<th>No. of teachers</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 years &amp; below</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>21-30 years</td>
<td>12</td>
<td>19</td>
</tr>
<tr>
<td>31-40 years</td>
<td>41</td>
<td>63</td>
</tr>
<tr>
<td>41-50 years</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Total</td>
<td>65</td>
<td>100</td>
</tr>
</tbody>
</table>

The majority of the science teachers (63%) were between 31 and 40 years of age. Only 22% of the teachers were younger than 31, and only 15% were older than 40 years.

Table 4.2

<table>
<thead>
<tr>
<th>Qualification</th>
<th>No. of teachers</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Teaching Qualification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- B.SC</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>NCE</td>
<td>24</td>
<td>37</td>
</tr>
<tr>
<td>B.Sc+PGDE</td>
<td>18</td>
<td>28</td>
</tr>
<tr>
<td>NCE+B.Sc/B.Ed/B.Sc. Ed</td>
<td>16</td>
<td>24</td>
</tr>
<tr>
<td>Total</td>
<td>65</td>
<td>100</td>
</tr>
</tbody>
</table>

Note, "NCE is the Nigerian Certificate in Education; "PGDE is the Postgraduate Diploma in Education.

Of the 65 science teachers, seven (11%) had science degrees but no professional teaching qualifications, 24 (37%) had a three year professional teaching qualification and the remainder (52%), had at least four years of pre-service teacher education. In addition to this, one respondent had a master of science degree and two had master degrees in education. The major subject areas of the teachers’ qualifications are summarised in Table 4.3.
Table 4.3

Major subject areas of the science teachers (N=65)

<table>
<thead>
<tr>
<th>Major subjects areas</th>
<th>No. of teachers</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Int.Sc+Bio/Chem/Phy/Math.</td>
<td>18</td>
<td>28</td>
</tr>
<tr>
<td>Bio; Bio+Agric/Chem.</td>
<td>18</td>
<td>28</td>
</tr>
<tr>
<td>Phy; Chem; Phy+Chem,</td>
<td>26</td>
<td>40</td>
</tr>
<tr>
<td>Agric. Science</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>65</td>
<td>100</td>
</tr>
</tbody>
</table>

*aThere are usually two subject areas in the Nigerian Certificate of Education. Subject areas found combined with Integrated Science are Biology, Chemistry, Physics and Mathematics.

Only 28% of the respondents had Integrated Science as a major subject area. A high proportion of teachers had their majors in the physical sciences. The teachers' years of teaching experience are summarised in Table 4.4

Table 4.4

Teachers' years of teaching experience (N=65)

<table>
<thead>
<tr>
<th>Years of experience</th>
<th>No. of teachers</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 and below</td>
<td>14</td>
<td>21</td>
</tr>
<tr>
<td>6-10</td>
<td>30</td>
<td>46</td>
</tr>
<tr>
<td>11-15</td>
<td>16</td>
<td>25</td>
</tr>
<tr>
<td>16-20</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>20 and above</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>65</td>
<td>100</td>
</tr>
</tbody>
</table>

The data indicate that the majority of the teachers (71%) have had between six and 15 years of teaching experience. Twenty-two percent of the teachers have had five years of teaching experience and below, while those who have had 16 years experience and above constituted just eight percent of the sample. The data also indicate that only one teacher has had up to 20 or more years of teaching experience which further suggests that most of the teachers do not stay their entire career in the teaching profession.
In summary, the majority of the teachers involved in this investigation were between 31 and 40 years of age and were female, had three or four years of teacher training, had no higher degrees in either sciences or education, and had less than 15 years of teaching experience.

**Assertion 4.1**
The majority of the science teachers were between 31 and 40 years of age, had three or four years of teacher training, and less than 15 years of teaching experience. Only 28% of the teachers had qualifications in Integrated Science.

**Class Size**

Teachers were asked to describe their class size. Responses were categorised into group data ranging from below 30 to 90-100, and are displayed in Figure 4.1. Class size by school location (urban/rural) is also summarised in Table 4.5.

![Figure 4.1. Class size](image)

Figure 4.1. *Class size (N = 65)*
Table 4.5

Class size distribution by school location (N = 63)

<table>
<thead>
<tr>
<th>Class size</th>
<th>Urban</th>
<th>Rural</th>
</tr>
</thead>
<tbody>
<tr>
<td>31-40</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>41-50</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>51-60</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>61-70</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>71-80</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>81-90</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>91-100</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>24</td>
</tr>
</tbody>
</table>

Note: Two teachers did not respond to this item.

The data indicate that the most common class sizes (54%) are between 51 and 70 students per class. Only 27% of classes had 50 students or less. Of the 39 schools in the urban areas, 19 (49%) have classes with more than 60 students whereas of the 24 rural schools, 7 (29%) have classes with more than 60 students per class. Classrooms in urban schools are generally larger than those of rural schools but the largest class (above 90) was found in a rural school.

Assertion 4.2
Most of the classes had between 51 and 70 students, and class sizes in rural schools were a little smaller than in urban schools.
Teachers' Beliefs about the Nature of Science and Science Teaching

Science teachers were asked to respond to statements about the nature of science on a five-point scale ranging from "strongly disagree" to "strongly agree". The percentages of teachers responding at the various levels of agreement were calculated. The teachers' responses to the various statements are summarised in Table 4.6.

Table 4.6

<table>
<thead>
<tr>
<th>Beliefs about the nature of science</th>
<th>SD (%)</th>
<th>D (%)</th>
<th>UN (%)</th>
<th>A (%)</th>
<th>SA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science theories are revised as new evidence is generated.</td>
<td>0.0</td>
<td>0.0</td>
<td>3.0</td>
<td>20.0</td>
<td>77.0</td>
</tr>
<tr>
<td>Scientific knowledge does not change</td>
<td>46.0</td>
<td>11.0</td>
<td>10.0</td>
<td>17.0</td>
<td>16.0</td>
</tr>
<tr>
<td>Science is a collection of facts about Nature</td>
<td>5.0</td>
<td>6.0</td>
<td>2.0</td>
<td>24.0</td>
<td>63.0</td>
</tr>
<tr>
<td>Science is a way of investigating and developing understanding about the natural world</td>
<td>26.0</td>
<td>21.0</td>
<td>14.0</td>
<td>25.0</td>
<td>14.0</td>
</tr>
</tbody>
</table>

Note: Not every teacher responded to all the items. SD = Strongly disagree; DA = Disagree; UN = Undecided; A = Agree and SA = Strongly agree.

Almost all respondents (97%) agree or strongly agree that science theories are revised as new evidence is generated and a majority of the teachers disagree or strongly disagree (57%) with the statement that scientific knowledge does not change. Very few of the teachers (39%) believe that science is a way of investigating and developing understanding about the natural world; however, most (87%) agree that science is a collection of facts about nature.

Assertion 4.3

Teachers' responses to statements about the nature of science indicate that they believe that science theories are revised as new evidence is generated, and that science is more of a collection of facts about nature rather than a way of investigating and developing understanding about the natural world.
Teachers were also asked to respond to statements about science teaching on a five-point scale ranging from "strongly disagree" to "strongly agree". The percentages of teachers responding at the various level of agreement were calculated. The responses are summarised in Table 4.7.

Table 4.7

<table>
<thead>
<tr>
<th>Teachers' beliefs about science teaching (N = 65)</th>
<th>SD (%)</th>
<th>D (%)</th>
<th>UN (%)</th>
<th>A (%)</th>
<th>SA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A quiet class is generally needed for effective science teaching and learning.</td>
<td>6.0</td>
<td>2.0</td>
<td>31.0</td>
<td>61.0</td>
<td></td>
</tr>
<tr>
<td>How much students learn depends on the relevance of the lesson to students' lives.</td>
<td>11.0</td>
<td>8.0</td>
<td>41.0</td>
<td>40.0</td>
<td></td>
</tr>
<tr>
<td>It is better when the teacher (not the student) decides what activities are to be done.</td>
<td>0.0</td>
<td>16.0</td>
<td>3.0</td>
<td>36.0</td>
<td>43.0</td>
</tr>
<tr>
<td>One of the most important factors influencing what a student learns in science is his/her existing knowledge and beliefs about the topic.</td>
<td>8.0</td>
<td>5.0</td>
<td>52.0</td>
<td>32.0</td>
<td></td>
</tr>
<tr>
<td>Students will take more initiative to learn when they feel free to move around the classroom.</td>
<td>31.0</td>
<td>29.0</td>
<td>7.0</td>
<td>21.0</td>
<td>12.0</td>
</tr>
<tr>
<td>Students should help establish the criteria that will be used to assess them.</td>
<td>24.0</td>
<td>45.0</td>
<td>11.0</td>
<td>17.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Note: SD=Strongly disagree, D=Disagree, UN=Undecided, A=Agree, SA=Strongly agree.

Almost all of the teachers (92%) agree or strongly agree with the statement that a quiet class is needed for effective teaching and learning, and most agree (79%) that the teacher should decide what activities are to be done. The majority of the teachers (69%) do not believe that students should feel free to move around the classroom or help establish criteria used for assessing them. Most teachers (81%) agree that the relevance of the lesson influences students' learning and (84%) agree that a student's existing knowledge and beliefs are important factors influencing learning.

Assertion 4.4

The teachers' agreed with statements about science teaching that are consistent with a teacher-centred style of teaching.
**Assertion 4.5**

Most teachers recognised the importance of relevance of lesson content and student’s existing knowledge for learning.

---

**Assertion 4.6**

Most teachers believe that it is the teacher (and not the student) that should decide what activities are to be done in the classroom and that a quiet class is generally needed for effective science teaching and learning.

---

**Organisation of Science Curriculum**

Teachers were asked to respond to statements about science curriculum organisation, on a five-point scale ranging from “strongly disagree” to “strongly agree”. The percentages of teachers responding at each level of agreement or disagreement were calculated. Responses to the statements are summarised in Table 4.8.
Table 4.8

*Teachers' beliefs about curriculum organisation (N = 65)*

<table>
<thead>
<tr>
<th>Beliefs about curriculum organisation</th>
<th>SD (%)</th>
<th>D (%)</th>
<th>UN (%)</th>
<th>A (%)</th>
<th>SA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science curriculum should be relevant to students' environment and lives.</td>
<td>2.0</td>
<td>2.0</td>
<td>0.0</td>
<td>17.0</td>
<td>79.0</td>
</tr>
<tr>
<td>Science curriculum should emphasise methods of inquiry in science</td>
<td>2.0</td>
<td>0.0</td>
<td>3.0</td>
<td>16.0</td>
<td>79.0</td>
</tr>
<tr>
<td>Science curriculum should emphasise content knowledge</td>
<td>3.0</td>
<td>4.0</td>
<td>2.0</td>
<td>21.0</td>
<td>70.0</td>
</tr>
<tr>
<td>Science curriculum should be based on societal issues</td>
<td>26.0</td>
<td>17.0</td>
<td>15.0</td>
<td>15.0</td>
<td>27.0</td>
</tr>
<tr>
<td>The content of the Lagos State's Integrated Science (ISC) curriculum is comprehensive.</td>
<td>5.0</td>
<td>4.0</td>
<td>3.0</td>
<td>10.0</td>
<td>78.0</td>
</tr>
<tr>
<td>Lagos State's ISC curriculum is flexible enough to enable me use various teaching methods.</td>
<td>6.0</td>
<td>5.0</td>
<td>9.0</td>
<td>10.0</td>
<td>70.0</td>
</tr>
<tr>
<td>Lagos State's ISC curriculum is current</td>
<td>24.0</td>
<td>18.0</td>
<td>19.0</td>
<td>18.0</td>
<td>21.0</td>
</tr>
<tr>
<td>Lagos State's ISC curriculum is relevant to students' needs</td>
<td>20.0</td>
<td>19.0</td>
<td>22.0</td>
<td>20.0</td>
<td>19.0</td>
</tr>
<tr>
<td>Lagos State's ISC curriculum objectives are achievable</td>
<td>25.0</td>
<td>9.0</td>
<td>28.0</td>
<td>22.0</td>
<td>16.0</td>
</tr>
</tbody>
</table>

*Note: SD=Strongly disagree, D=Disagree, UN=Undecided, A=Agree, and SA=Strongly agree.*

The data summarised in Table 4.8 indicate that almost all teachers (96%) strongly agree or agree with the statement that the curriculum should be relevant to students' environment and lives. They also believe that the curriculum should emphasise both content knowledge (91%) and methods of inquiry (95%) but only a minority (42%) favour a curriculum based on societal issues. Most teachers (88%) view the Lagos State's Integrated Science curriculum as comprehensive, however, only a minority believe that the Integrated Science curriculum is current (39%), is relevant to students' needs (39%), and has achievable objectives (38%).

**Assertion 4.7**

Almost all of the teachers believe that the curriculum should be relevant and it should be based on inquiry in science and on content knowledge.
Assertion 4.8
A majority of teachers agree that the Lagos State's Integrated Science curriculum is comprehensive; however, they do not believe that the document is current, relevant to students' needs or has achievable objectives.

Teaching and Learning in Science

This section considers the strategies used by teachers in their science teaching, the average time usually spent on each teaching strategy, and goals for asking students questions during science lessons.

Strategies Used

Respondents were asked to describe their last Integrated Science lesson in terms of classroom practices and/or any strategies employed. Various responses were given ranging from explaining, demonstrating to making use of models or specimens. The responses are summarised in Table 4.9.
### Table 4.9

Teaching strategies used by teachers in their last science lesson ($N = 65$).

<table>
<thead>
<tr>
<th>Classroom practices/strategies</th>
<th>Frequency</th>
<th>% Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explaining</td>
<td>43</td>
<td>66.2</td>
</tr>
<tr>
<td>Demonstrating</td>
<td>19</td>
<td>29.2</td>
</tr>
<tr>
<td>Giving examples</td>
<td>15</td>
<td>23.1</td>
</tr>
<tr>
<td>Engaging students in class discussion</td>
<td>7</td>
<td>10.8</td>
</tr>
<tr>
<td>Defining science terms</td>
<td>4</td>
<td>6.2</td>
</tr>
<tr>
<td>Giving notes</td>
<td>4</td>
<td>6.2</td>
</tr>
<tr>
<td>Giving class activities</td>
<td>4</td>
<td>6.2</td>
</tr>
<tr>
<td>Using models/objects/specimens</td>
<td>4</td>
<td>6.2</td>
</tr>
<tr>
<td>Guiding students</td>
<td>4</td>
<td>6.2</td>
</tr>
<tr>
<td>Using charts/diagrams</td>
<td>3</td>
<td>4.6</td>
</tr>
<tr>
<td>Summarising concepts</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>Asking and answering questions</td>
<td>1</td>
<td>1.5</td>
</tr>
</tbody>
</table>

**Note:** % Percentage of teachers mentioning each strategy.

The data indicate that the most frequently mentioned strategies were explaining (66.2%), demonstrating (29.2%) and giving examples to students (23.10%). It should be noted that there are a number of teaching strategies like giving notes, and using charts/diagrams that are related to explaining or may have been used in the course of explaining. The responses strongly support an emerging pattern of instructional style that is teacher-centred and didactic.
Assertion 4.9

The teachers' descriptions of their last lesson indicate that the most frequently employed teaching strategies are explaining, demonstrating and giving examples.

As a follow-up question, teachers were asked to indicate if the described lesson was typical of other lessons they taught in school and whether they considered the lesson effective or not and to give the reason why. Ninety-two percent of the teachers indicated that the lesson described, was typical of other lessons they taught in their schools. Of the remaining 8% who indicated that it was not typical of their lessons, 4% gave the reason that the lesson involved the use of real objects/specimens, 2% noted that their lessons involved abstract concepts, which students found difficult to understand and 2% gave the reason that, their lessons involved practicals.

Fifty-nine percent of the teachers indicated that they considered the lesson effective and gave reasons, which are summarised in Table 4.10, while 5% indicated that their own lessons were not effective because of the large class size and 2% considered their lesson ineffective because of poor sitting arrangements in class.

Table 4.10

Teachers' reasons for considering their lessons effective (N=38)

<table>
<thead>
<tr>
<th>Reasons for considering the lesson effective</th>
<th>No of teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students respond to questions</td>
<td>17</td>
</tr>
<tr>
<td>Students show interest in the concept</td>
<td>8</td>
</tr>
<tr>
<td>Students contribute to class discussion</td>
<td>6</td>
</tr>
<tr>
<td>Students participate in demonstration</td>
<td>5</td>
</tr>
<tr>
<td>Students were made to observe real objects/specimens</td>
<td>2</td>
</tr>
</tbody>
</table>

The teachers explained that students answering questions in class, showing interest in the concept being taught, contributing to class discussion and participating in demonstrations are
important indicators of effective science teaching. These teachers seemed to view students' engagement in their lessons as signs that the lessons were effective.

Time Spent on Various Teaching Strategies

Science teachers were asked to estimate the time they spent on various teaching strategies during a typical 40 minutes science lesson and during a typical 80 minutes practical lesson. Teachers' estimates of the time spent on each strategy were summed and their mean values calculated. The mean times spent and their standard deviations are summarised in Table 4.11 and Table 4.12.

Table 4.11

Mean estimated time spent on (or assigned to) teaching strategies in a typical 40 minutes lesson (N = 65)

<table>
<thead>
<tr>
<th>Teaching strategies</th>
<th>Average time (mins)</th>
<th>Standard deviation</th>
<th>Percentage of lesson</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher explaining</td>
<td>15.7</td>
<td>5.5</td>
<td>39.4</td>
</tr>
<tr>
<td>Giving notes to students</td>
<td>9.4</td>
<td>3.3</td>
<td>23.3</td>
</tr>
<tr>
<td>Whole-class discussion</td>
<td>5.7</td>
<td>4.7</td>
<td>14.2</td>
</tr>
<tr>
<td>Supervising students' work</td>
<td>5.5</td>
<td>3.3</td>
<td>13.8</td>
</tr>
<tr>
<td>Small group activities</td>
<td>2.4</td>
<td>2.8</td>
<td>6.0</td>
</tr>
<tr>
<td>Students reading text books</td>
<td>1.3</td>
<td>2.4</td>
<td>3.3</td>
</tr>
<tr>
<td>Total</td>
<td>40.0</td>
<td></td>
<td>100.0</td>
</tr>
</tbody>
</table>

The data indicate that the teachers spend most of the time in a lesson explaining the concepts (39.4%) and giving notes to students (23.3%). Time spent on students' small group activities and reading of textbooks is quite minimal.

Assertion 4.10

The teachers' responses indicate that, on average, they spend more than half of 40 minutes lessons explaining concepts and giving notes to students.
Table 4.12

Mean estimated time spent on teaching strategies in a typical 80 minutes practical lesson

\((N = 63)\)

<table>
<thead>
<tr>
<th>Teaching strategies</th>
<th>Average time (mins)</th>
<th>Standard deviation</th>
<th>Percentage of lesson</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students' group work/activities</td>
<td>21.9</td>
<td>10.3</td>
<td>27.4</td>
</tr>
<tr>
<td>Teacher's demonstration</td>
<td>20.3</td>
<td>9.1</td>
<td>25.4</td>
</tr>
<tr>
<td>Teacher explaining</td>
<td>11.6</td>
<td>5.9</td>
<td>14.6</td>
</tr>
<tr>
<td>Giving note to students</td>
<td>10.4</td>
<td>7.1</td>
<td>13.0</td>
</tr>
<tr>
<td>Individual student's activities</td>
<td>8.8</td>
<td>7.9</td>
<td>11.0</td>
</tr>
<tr>
<td>Whole-class discussion</td>
<td>7.0</td>
<td>5.2</td>
<td>8.6</td>
</tr>
<tr>
<td>Total</td>
<td>80.0</td>
<td></td>
<td>100.0</td>
</tr>
</tbody>
</table>

Even in 80 minutes practical lessons, teachers spend more than half of the lesson on teacher-centred activities involving demonstrating, explaining and giving notes to students. Students' group and individual activities are only allocated a total of 31 minutes (38.4%). Students are rarely involved in whole-class discussions during practicals.

**Assertion 4.11**

During 80 minutes practical periods more than half of the period is spent on teacher-directed activities involving teacher demonstration, explanation of concepts and giving notes to students rather than on students' group/individual activities.

**Goals for Asking Students Questions during Science Lessons**

Teachers were asked how often they were trying to accomplish certain goals by asking students questions. They were specifically asked to respond, on a four-point scale ranging
from "never" to "very often", to statements about goals for asking students questions during science lessons. The statements and the percentages of the teachers’ responses at various levels of agreement were calculated and are summarised in Table 4.13.

Table 4.13

*Teachers’ goals for asking students questions during science lesson (N = 65)*

<table>
<thead>
<tr>
<th>Goals for asking students questions</th>
<th>Percentage of teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Never</td>
</tr>
<tr>
<td>To make students relate what they are learning to their own experience</td>
<td>0.0</td>
</tr>
<tr>
<td>To elicit the students’ ideas or opinions</td>
<td>3.1</td>
</tr>
<tr>
<td>To get the students to explain their reasoning</td>
<td>3.1</td>
</tr>
<tr>
<td>To see if students know the correct answer</td>
<td>6.2</td>
</tr>
<tr>
<td>To see if they have done their homework</td>
<td>3.1</td>
</tr>
</tbody>
</table>

Even though teachers sometime or often ask students questions during lessons in order to know if students know the correct answer or whether they have done their homework, the data indicate that more often they ask questions in order to elicit students’ ideas (83.1%) and to make them relate what they learn to their own experience (84.6%). However, more than 90% of the teachers sometime, often or very often ask questions to determine if homework has been completed.

**Assertion 4.12**

The teachers’ responses indicate that they more often ask students questions to make them relate the concept to their own experience or to elicit students’ ideas or opinions than they do so in order to know if students have done their homework or if they know the correct answer.

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Practical Science Lessons

Teachers were asked to indicate, on a four-point scale ranging from “never” to “all the time” how often they gave students the procedure to follow for experiments, and how often they allowed students to plan their own investigations. The teachers’ responses are summarised in Table 4.14

Table 4.14

How often teachers give students procedures for experiments or allow them to plan their own investigations (N=65)

<table>
<thead>
<tr>
<th>Statements</th>
<th>Percentage of teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td>How often do you give students the procedure to follow for experiments</td>
<td>Never</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td>How often do you allow students to plan their own practical investigation</td>
<td>24</td>
</tr>
</tbody>
</table>

The data summarised in Table 4.14 indicate that the large majority of teachers (86%) give students practical procedures to follow most of the time or all the time. Twenty-four percent indicated that they never allow students to plan their own experiments while 76% only allow this occasionally.

Assertion 4.13

The majority of the teachers provide students the procedures to follow for experiments most of the time and they rarely allow students plan their own investigations.

Teachers were asked to rate, on a four-point scale varying from “not available at all” to “very good”, the state of instructional facilities for teaching practical lessons in their schools. The teachers’ ratings of their facilities for practical lessons are summarised in Table 4.15.
Table 4.15

Teachers' ratings of the state of facilities for teaching practical lessons in their schools

(N = 65)

<table>
<thead>
<tr>
<th>State of facilities</th>
<th>No. of teachers</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not available at all</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Very poor</td>
<td>29</td>
<td>45</td>
</tr>
<tr>
<td>Adequate</td>
<td>29</td>
<td>45</td>
</tr>
<tr>
<td>Very good</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>65</td>
<td>100</td>
</tr>
</tbody>
</table>

The data indicate that more than 46% of the science teachers were of the opinion that the facilities for teaching practical lessons in their schools were either not available or were very poor. Only 9% of teachers rated their facilities as very good.

Assertion 4.14

The teachers' responses indicate that in almost half of the schools involved in this study, the facilities for teaching practicals were not available or poor.

Purpose of Assessing Students in Schools

Teachers were asked to list in order of importance, four purposes for assessing students in their schools. Responses in the four categories of importance were given weightings of first (4) second (3) third (2) and fourth (1). The total weighted rank order was calculated by multiplying each purpose of assessing students listed as first, second, third, and fourth by their respective weighing factors of four, three, two, and one. The various purposes for assessing
students in schools listed by the teachers and their weighted rank order of importance are summarised in Tables 4.16.

Table 4.16

**Purposes of assessing students in schools nominated by teachers and their rank order of importance (N = 65)**

<table>
<thead>
<tr>
<th>Purposes of assessing students in schools</th>
<th>Weighted rank order of importance</th>
<th>Total weighted rank scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First (x 4)</td>
<td>Second (x 3)</td>
</tr>
<tr>
<td>To test students' ability</td>
<td>72</td>
<td>36</td>
</tr>
<tr>
<td>For promotion to the next class</td>
<td>28</td>
<td>30</td>
</tr>
<tr>
<td>To know if lesson objective is achieved</td>
<td>56</td>
<td>15</td>
</tr>
<tr>
<td>To find out if they understand concept</td>
<td>48</td>
<td>12</td>
</tr>
<tr>
<td>To evaluate one's self</td>
<td>16</td>
<td>24</td>
</tr>
<tr>
<td>To give feedback to parents</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>To find out problem areas in the scheme of work</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>To keep records of students</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>To encourage students</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>To determine students' scores</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>To improve teaching</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>232</td>
<td>159</td>
</tr>
</tbody>
</table>

*Note: The weighed ranks were calculated by multiplying the purposes of assessment in schools ranked first, second, third, and fourth respectively by the weighing factors of four, three, two and one.*

The data (Table 4.16) indicate that the most important purposes of assessing students are, to test students' ability, for students' promotion to the next class, to find out if lesson objectives
are achieved and to find out if students understand the concepts. Other purposes for assessing students in schools include to evaluate one's self as the teacher, to give feedback to parents, to find out problem areas in the scheme of work, to keep records of students' achievements in the school, to encourage students in their studies, to determine students' scores and to improve teaching. The raw data also indicate that there is considerable variation between teachers in their rating of purposes for assessing students in schools.

Assessment Methods

Teachers were asked to list in order of importance, four assessment methods that were being used in science in their schools. Responses that fell into the first (4), second (3), third (2) and fourth (1) priority lists of the teachers' nominated assessment methods in their schools were multiplied by weighting factors and the data are summarised in Table 4.17.

Table 4.17

Teachers' nominated assessment methods used in school and their weighted rank order of importance \((N = 65)\).

<table>
<thead>
<tr>
<th>Assessment method</th>
<th>Weighted rank order of importance</th>
<th>Total weighted rank scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First (x 4)</td>
<td>Weighted rank score (x 3)</td>
</tr>
<tr>
<td>Periodic/Continuous assessment tests</td>
<td>92</td>
<td>48</td>
</tr>
<tr>
<td>Regular class exercises</td>
<td>32</td>
<td>27</td>
</tr>
<tr>
<td>Take-home assignments</td>
<td>32</td>
<td>27</td>
</tr>
<tr>
<td>Terminal examinations</td>
<td>24</td>
<td>27</td>
</tr>
<tr>
<td>Projects</td>
<td>12</td>
<td>18</td>
</tr>
<tr>
<td>Grading of practical notes</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>Attendance in class</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Assessment of skills</td>
<td>8</td>
<td>--</td>
</tr>
<tr>
<td>Total</td>
<td>220</td>
<td>153</td>
</tr>
</tbody>
</table>

Note: Not every teacher responded to this item. The weighted rank scores were calculated by multiplying the assessment methods ranked first, second, third and fourth by their weighing factors of four, three, two and one respectively.
The data indicate that by far the most practiced methods of assessment in schools are periodic/continuous assessment tests, regular class exercises, take-home assignments, and terminal examinations. Grading of practical notes and use of projects are also used by (16%) teachers).

**Assertion 4.15**
The teachers' responses indicate that the majority of them assess their students by giving periodic/continuous assessment tests, regular class exercises, take-home assignments and by terminal examinations and they do so more often for summative purposes rather than for formative purposes.

**Role of Students**

Respondents were asked to describe the role/s played by their students during their most recent Integrated Science lesson. Responses ranged from just listening and paying attention to taking notes during the lesson. The various responses regarding the roles/activities of students during a science lesson and percentage of teachers identifying them are summarised in Table 4.18.
Table 4.18 Role of students during a science lesson and percentage of teachers mentioning them (N = 65)

<table>
<thead>
<tr>
<th>Students' roles/activities</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Listening</td>
<td>28</td>
<td>43</td>
</tr>
<tr>
<td>Asking/answering questions</td>
<td>27</td>
<td>42</td>
</tr>
<tr>
<td>Taking notes</td>
<td>19</td>
<td>29</td>
</tr>
<tr>
<td>Engaged in group activities</td>
<td>14</td>
<td>22</td>
</tr>
<tr>
<td>Observing the teacher</td>
<td>13</td>
<td>20</td>
</tr>
<tr>
<td>Discussing</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>Engaged in individual activities</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Note: Most teachers mentioned several student roles.

The data displayed in Table 4.18 indicate that during the teachers' last science lessons students were mainly involved in such activities as listening (43.1%), asking/answering questions (41.5%), or just answering questions (36.9%). More than half of the responses referred to the students' passive roles of listening, observing the teacher or copying notes. Engaging in individual activities and class discussions were least reported, (3.1%) and (12.3%) respectively.

Assertion 4.16

The teachers' descriptions of the roles of students in their last lesson indicate that in the majority of the lessons students were mainly performing passive roles of listening, answering questions and taking down notes.

Teachers were further asked to outline students' roles in an effective science classroom. Specifically, they were asked to respond to the statement: "I believe science teaching and learning is most effective when the students do or are doing the following:" Various responses
were given regarding students' roles when science teaching and learning is most effective. The number of times each role/activity was suggested by the teachers (frequency) and percentage of teachers nominating them are summarised in Table 4.19.

Table 4.19

Typical students' roles/activities when science teaching and learning is considered most effective (N = 65).

<table>
<thead>
<tr>
<th>Role of students</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engaged in hands-on activities</td>
<td>34</td>
<td>52</td>
</tr>
<tr>
<td>Ask and answer questions in the class</td>
<td>33</td>
<td>51</td>
</tr>
<tr>
<td>Listen attentively and follow instructions</td>
<td>25</td>
<td>39</td>
</tr>
<tr>
<td>Do all assignments</td>
<td>13</td>
<td>20</td>
</tr>
<tr>
<td>Find out things on their own</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Keep good notes</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>Contribute to class discussions</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>Can adequately observe teacher's demonstration</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Show interest in the study of science and are keen to</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>explore more</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Relate very well with their teacher</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Can apply previous knowledge to tackle new problems</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Note: Most teachers mentioned several student roles.

Most of the teachers hold the belief that science teaching and learning is most effective when students are engaged in hands-on activities (52.3%), ask and answer questions in the class (50.8%), listen and follow instructions (38.5%), and do all assignments (20.0%). Finding out things on their own, contributing to class discussions and keeping of good notes were also mentioned. Even though 52.3% of the teachers mentioned students' engagement in hands-on activities as most crucial when science teaching is most effective, the strategy was least employed in their own description of the students' roles during their last science lessons described in Table 4.18. The assertion could be reasonably made that the teachers were either not guided by their pedagogical beliefs about learning during their last lesson or tried to avoid a
more challenging instructional method or were constrained by other factors such as class size or lack of facilities in their schools.

**Assertion 4.17**

A comparison of students' roles in the teachers' last lesson (summarised in Table 4.18) and the teachers' belief that students be engaged in hand-on activities when science teaching and learning is most effective (Table 4.19), indicate that the teachers seem not to have been guided by their pedagogical beliefs during their last lessons or may have been constrained by school factors such as lack of facilities or large classes.

---

**Teachers' Roles**

Teachers were asked to state the role/s of the teacher when science teaching is effective. Specifically, they were asked to respond to the statement, "Science teaching is effective when the teacher does...?" Many of the teachers suggested three or more roles and teaching strategies ranging from demonstrating the concept being taught to proper planning ahead for lessons. Though most of the responses were related and interwoven, they fell into clusters relating to teacher's knowledge about teaching, general (more traditional) teaching styles, more student-oriented strategies and class control. The percentage of teachers suggesting the various teaching roles and strategies within each of these identified clusters are summarised in Table 4.20.
Table 4.20

Percentage of teachers suggesting various teaching roles/strategies for effective science teaching (N = 65)

<table>
<thead>
<tr>
<th>Teacher's roles/strategies when science teaching is effective</th>
<th>No of teachers</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strategies relating to teachers' knowledge and lesson preparation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has good knowledge of subject matter</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>Possesses the ability to improvise teaching materials</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>Plans very well ahead of lesson</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Organises his/her lesson from simple to complex</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Takes into account the developmental level of students</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Makes use of appropriate evaluation method</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>General teaching (more traditional) strategies</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demonstrates the concept being taught.</td>
<td>34</td>
<td>52</td>
</tr>
<tr>
<td>Explains the concept effectively</td>
<td>25</td>
<td>39</td>
</tr>
<tr>
<td>Relates the concept to students' lives</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>Makes use of instructional materials</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>Uses real objects/specimens</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Uses various teaching skills</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Gives enough exercises and examples</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Give notes to the students on each topic taught</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Arouses students' interest in the concept</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>More student-oriented strategies</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ensures that students learn by doing activities</td>
<td>19</td>
<td>29</td>
</tr>
<tr>
<td>Supervises individual students' work</td>
<td>11</td>
<td>17</td>
</tr>
<tr>
<td>Allows students' participation in the lesson</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Encourages students to ask and answer questions</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>Encourages students to find out things by themselves</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>Gives the topic out to students ahead of the lesson</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Engages students in class discussion</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td><strong>Strategies relating to class control</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Directs and adequately manages the classroom</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>
In terms of teacher's background knowledge and lesson preparation, a good number of teachers (14%) hold the belief that science teaching is most effective when the teacher has good knowledge of subject matter and can improvise teaching materials (11%) when necessary.

A large majority of the teachers believe that teaching is effective when the teacher demonstrates (52%) and effectively explains (39%) the concept being taught and relates it to students' lives (12%). Those responses indicate that the majority of the teachers hold beliefs consistent with transmission pedagogy. Nevertheless, a good number of teachers do believe in more student-oriented strategies; that science teaching is most effective when the teacher allows students' participation in the lesson (15%), ensures that they learn by doing activities (29%), and supervises their individual work (17%).

<table>
<thead>
<tr>
<th>Assertion 4.18</th>
</tr>
</thead>
<tbody>
<tr>
<td>For effective science teaching, the majority of teachers believe that the concept should be demonstrated and explained effectively, and to do this teachers need a good knowledge of subject matter.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assertion 4.19</th>
</tr>
</thead>
<tbody>
<tr>
<td>A large minority of the teachers also believe that science teaching is most effective when the teacher allows students to participate in the lesson, ensures that they learn by doing hands-on activities, encourages them to ask and answer questions in class and supervises their work individually.</td>
</tr>
</tbody>
</table>

Classroom Environment/Facilities

The teachers were asked to give a rating of the classroom environment/facilities for science teaching in their schools on a three-point scale ranging from "good enough to "inadequate". The teachers' ratings of their classroom environment/facilities are summarised in Table 4.21.
Table 4.21

*Teachers' rating of their classroom environment/facilities (N=58)*

<table>
<thead>
<tr>
<th>Classroom environment/facilities</th>
<th>No of teachers</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good enough</td>
<td>24</td>
<td>41</td>
</tr>
<tr>
<td>Averagely all right</td>
<td>14</td>
<td>24</td>
</tr>
<tr>
<td>Inadequate</td>
<td>20</td>
<td>35</td>
</tr>
</tbody>
</table>

*Note: Not every teacher responded to this item. Classroom environment/facilities for science teaching include: enough room and furniture, charts, models, objects/specimens, workbooks etc.*

The majority of the teachers believe that their classroom environment/facilities were good enough (41%) or averagely ok (24%) for effective science teaching and learning. A good number of teachers (35%) also hold the view that their classroom environments/facilities were inadequate for effective science teaching and learning.

**Assertion 4.20**

The teachers' ratings of their classroom environment/facilities indicate fairly divided opinions; more than a third of the science teachers sampled rated the classroom environment/facilities in their schools as inadequate; this view appears to agree with the teachers' views regarding facilities for practical lessons (Assertion 4.14).

**Factors that Inhibit Effective Science Teaching**

Teachers were asked to list four major factors, in order of importance, that inhibit or limit the effectiveness of their science teaching. The inhibiting/limiting factors listed as first, second, third, and fourth in their level of importance and their overall weighted ranking order are summarised in Tables 4.22.
Table 4.22
Factors identified by teachers as inhibiting science teaching effectiveness and their weighted rank order of importance (N=65)

<table>
<thead>
<tr>
<th>Factors that inhibit effectiveness</th>
<th>First (x 4)</th>
<th>Second (x 3)</th>
<th>Third (x 2)</th>
<th>Fourth (x 1)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limited resources</td>
<td>80</td>
<td>45</td>
<td>14</td>
<td>2</td>
<td>141</td>
</tr>
<tr>
<td>Lack of appropriate text-books</td>
<td>16</td>
<td>24</td>
<td>22</td>
<td>5</td>
<td>67</td>
</tr>
<tr>
<td>Students’ poor attitude</td>
<td>20</td>
<td>24</td>
<td>16</td>
<td>5</td>
<td>65</td>
</tr>
<tr>
<td>Class size</td>
<td>44</td>
<td>12</td>
<td>2</td>
<td>2</td>
<td>60</td>
</tr>
<tr>
<td>Inadequate laboratory</td>
<td>24</td>
<td>27</td>
<td>6</td>
<td>2</td>
<td>59</td>
</tr>
<tr>
<td>Unconducive environment</td>
<td>12</td>
<td>18</td>
<td>8</td>
<td>2</td>
<td>40</td>
</tr>
<tr>
<td>Inadequate job motivation</td>
<td>8</td>
<td>9</td>
<td>16</td>
<td>6</td>
<td>39</td>
</tr>
<tr>
<td>Insufficient time for each period</td>
<td>20</td>
<td>6</td>
<td>4</td>
<td>6</td>
<td>36</td>
</tr>
<tr>
<td>Lack of support from parents</td>
<td>0</td>
<td>3</td>
<td>12</td>
<td>2</td>
<td>17</td>
</tr>
<tr>
<td>Poor background of students</td>
<td>8</td>
<td>6</td>
<td>0</td>
<td>1</td>
<td>15</td>
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<tr>
<td>Cultural beliefs of the community</td>
<td>8</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>Insufficient number of teachers</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Too much work load</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Insufficient free-hand (freedom)</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Students are not allowed to learn science out of classroom</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>240</td>
<td>177</td>
<td>112</td>
<td>40</td>
<td>569</td>
</tr>
</tbody>
</table>

Note: The weighted rank order was calculated by multiplying the teachers' rankings by the weighing factors of four, three, two and one respectively.
The data indicate that science teachers identified 16 factors, which inhibit or limit their effectiveness in science teaching in their schools. Of these inhibiting factors, by far the most significant, starting from the most important, are limited resources, lack of appropriate textbooks, students' poor attitude towards science, large classes, inadequate laboratory facilities, and lack of job motivation among others.

**Assertion 4.21**
The five most important factors limiting the quality of science teaching that were mentioned by the teachers were: limited resources, lack of appropriate textbooks, students' poor attitude towards science subjects, large class size, and inadequately equipped laboratory.

**Summary of Findings**

The majority of the science teachers were between 31 and 40 years of age, had three or four years of teacher training, had a major in the physical sciences and less than 15 years of teaching experience. Most of the classes had between 51 and 70 students and class sizes in the rural schools were a little smaller than in urban schools.

The teachers' responses to statements about the nature of science indicate that they believe that science theories are revised as new evidence is generated, that science is a collection of facts rather than a way of investigating and developing understanding about the natural world. The teachers agreed with statements about science teaching that was consistent with teacher-centred, didactic teaching styles. They did not agree with statements about students being free to move round the classroom or establishing assessment criteria and this further suggest that they hold beliefs about teaching consistent with traditional teaching philosophies.

The teachers' responses to statement about curriculum organisation indicate that they strongly believe that curriculum should be relevant and it should be based on inquiry in science and on content knowledge. They agreed that the Lagos State's Integrated Science curriculum is comprehensive; however, the majority of them do not view the document as current, relevant to students' needs or having achievable objectives.
The teachers' descriptions of their last lesson indicate that their most frequently employed teaching strategies are explaining, demonstrating and giving examples. On the average, they spend more than half of the period in any 40 minutes lesson explaining the concept and giving notes to students. During 80 minutes practical periods more than half of the period is spent on teacher-directed activities involving teacher demonstration, explanation of concepts and giving notes to students rather than on students' group/individual activities.

The teachers' responses indicate that they more often ask students questions in order to help them relate concepts to their own experience or to elicit students' ideas or opinions than they do so in order to know if students have done their homework or if they know the correct answer. The majority of the teachers give practical procedures for their students to follow most of the time or all of the time during practical classes and they rarely allow students plan their own investigations. In about half of the schools involved in this study, the state of facilities for teaching practicals is very poor.

The teachers' responses about purposes for assessing students in schools indicate that the majority of them assess their students for summative purposes rather than for formative purposes. The majority of them assess their students by giving periodic/continuous assessment tests, regular class exercises, and take-home assignments and by terminal examinations.

The teachers' description of the roles of students in their last lesson indicate that in the majority of the lessons students were mainly listening, asking and answering questions and taking down notes. The majority of the teachers hold the view that science teaching and learning is most effective when students are engaged in hands-on activities ask and answer questions in class and listen attentively and follow instructions. A minority of them, however, are of the view that science teaching and learning is most effective when the students are allowed to find out things on their own, contribute to class discussions, and show interest in the concept being taught.

A comparison of students' roles in the teachers' last lesson (summarised in Table 4.18) and the teachers' suggested roles of students when science teaching is most effective (Table 4.19) indicate that the teachers may have been constrained by school factors such as lack of facilities or large classes.
For effective science teaching, the majority of the teachers believe that the concepts should be demonstrated and explained effectively, and to do this teachers need a good knowledge of subject matter. A large minority of them also believe that science teaching is most effective when the teacher allows the students to participate in the lesson, ensures that they learn by doing hands-on activities, encourages them to ask and answer questions in class and supervises their work individually. The teachers' ratings of their classroom environment/facilities indicate fairly divided opinions; more than one third of the science teachers sampled rated the classroom environment/facilities in their schools as inadequate – this view appears to agree with the teachers' views regarding facilities for practical lessons.
CHAPTER 5: CASE STUDY 1

Introduction

This Chapter presents the first case study. The case studies presented in the next three chapters were conducted in order to investigate more closely the teachers' beliefs about effective science teaching, how they teach and why they teach the way they do, and to find out what component or attribute of PCK that manifest in their classroom practices. The case study presented in this Chapter was compiled from data gathered by questionnaire, interview, lesson observations, informal discussions and analysis of curriculum documents. It is presented in six parts. Presented first is the teacher’s profile followed by the context of science teaching in the school. The third part outlines the teacher’s pedagogical beliefs while the fourth presents the teacher’s classroom practices. The teacher’s practices were analysed in terms of pedagogical content knowledge (PCK) in the fifth part, and the sixth part summarises the chapter.

Teacher’s Profile

Tello is a 35-year old science teacher in an urban school in the Lagos metropolis. He had been teaching science at the secondary school level for 10 years, four of which were in his present school. He started his teaching career as a graduate teacher with a bachelor’s degree in biochemistry, without any teaching qualification. Tello decided to go to the University to acquire a Post Graduate Diploma in Education (PGDE) after he had taught for two years. Tello was posted to his present school four years ago, and is currently the acting head of science department in the school.

Among Tello’s current job functions in the school are to provide instruction in science consistent with the Local Education District and school expectations which meet the needs of all students assigned to him. He is also to employ planning, record keeping, resource management and learning environment management practices which are consistent with the District and school expectations and which maximises his effectiveness (interview with Vice Principal, 7/2/02; Federal Ministry of Education (FME), 1980). He is one of two Integrated Science teachers in the school and his involvement in teaching Integrated Science in the junior secondary level is 26 periods per week, six of which are assigned to three double-periods of practical classes.
Context of Science Teaching

Tello's school is an urban secondary school located in a school village complex comprising four secondary schools in Ojo Local Education District of Lagos State of Nigeria. The school is located in an urban area of Lagos where the people are predominantly civil servants, industry workers, businessmen and small-scale self-employed individuals. People in the local community have a positive disposition towards education and almost every child of school age in the area attends school. Tello's school is co-educational with a population of about 4,000 students. Integrated Science is taught as a compulsory subject at the junior secondary level. Each of the years has between four and five streams. The school has a separate laboratory for Integrated Science in addition to those for Chemistry, Biology, Physics and Agricultural Science.

Integrated Science is taught in the school based on the content and guidelines in the National Integrated Science Curriculum for Junior Secondary Schools (JSS 1-3) (FME, 1980) and the Lagos States Unified Scheme of Work for Integrated Science (Lagos State Ministry of Education, 2001/2002), which itemised the science content to be covered each week over the three school terms. Other documents that Tello makes use of in his teaching include teacher's diary, lesson notes, teacher's handbook, continuous assessment record book (mark book) and teacher's weekly timetable. These documents are considered essential for effective teaching in the Lagos State school system and signatures of superior officers and school inspectors were seen visible on most of them, indicating that other officers in the school system were supervising the teaching materials. The Integrated Science curriculum prescribes the teaching activities and suggests alternative procedures for students' activities.

The School's Integrated Science laboratory appeared averagely equipped judging from the number and type of science teaching materials found in it. Displayed on the side benches were flasks of various sizes, about 20 Bunsen burners, glass jars, both glass and plastic funnels, about 10 microscopes, about 25 hand lenses of various types, models of mammalian skeletons, and charts of the periodic table, organs of the body, energy pyramid and so on. Labelled bottles of reagents were seen organised in rows on a shelf across one side of the laboratory and there were two cupboards in which reagents bottles, filter papers, indicators and electrical equipments were kept. The laboratory was
provided with water and electricity. There were sufficient benches and seats for all students in the classes. The classrooms were also fairly adequate considering what is typical of most schools in Lagos State. Tello had between 45 and 54 students in each of the Integrated Science classes he taught, and the students were all seated because there were enough seats and benches in each of the classrooms. Overall the school appeared to be typical in terms of facilities for science teaching based on what exists in most schools in the area and the classroom environment was conducive to learning except for the class sizes that, on the average, are about 50 students or above.

Teacher’s Views

The Nature of Science

Tello believes that science is the study of the natural world; a study of things that are visible or that can be touched in the natural environment. Tello believes that science is a collection of facts about nature. Even though he feels that science theories may be revised as new evidence is generated, he believes that scientific knowledge does not usually change (Survey Questionnaire, 3.7, 8, 10). Explaining what he believes science is, he stated:

Science is the study of the natural world; things that exists in nature. These things are concrete…I guess it has to be made concrete or real as we teach it so that the students, whom we are teaching, should be able to get something out of it. This is because of the fact that it is the study of nature and in some cases it can appear to be abstract...so, I guess the more we concretise issues in science the better these students will get the best out of it...(Interview with Tello, 8/2/02)

Tello believes that the science curriculum should emphasise both content knowledge and inquiry in science and should be relevant to the students’ environment and lives (Survey Questionnaire, 5.1, 2, 4) He wants his students to view science as the study of things they can see in their natural environment, things they should be able to talk about in their environment (giving as examples, the moon and the sky as parts of the natural environment), he explained:
...That is the moon and that is the sky...they are parts of nature...both can be seen by the students; they can talk about them... but to be able to do so, we need to concretise them as we teach... and I would advise our curriculum planners... and the school to try and provide instructional materials that will help us present these things to our students in a way they can easily understand and make sense of it (Interview with Tello 8/2/02).

Tello's emphasis on knowledge of facts and reality about the natural world seems to support his belief in absolute truth in science. He believes that science is taught to students in schools to enable them have knowledge of the realities about the natural world that they live in and to prepare them for science-related professions. He explained:

...Knowing about the realities about the natural world will enable them to appreciate the work of nature... aesthetic feelings will be aroused in them...so that they can get to know scientific facts...for example, what happens to the food they eat in their body... how digestion takes place and knowledge of many things they make use of in their daily lives. We must not forget the fact that we also teach science to them in order to prepare them for science-based professions in future life... (Interview with Tello 8/2/02).

Though Tello believes that the Lagos State Integrated Science curriculum is comprehensive, relevant to students' needs and has achievable objectives, he does not believe that the document is current or flexible enough to enable him apply various teaching methods (Survey Questionnaire, 5.5). He believes that the curriculum already prescribes the teaching methods to be used and he could therefore not employ other methods of his choice.

**Assertion 5.1**

Tello believes that science is the study of "concrete things or phenomena" which exist in the natural world and that science is a collection of facts about those things.
Assertion 5.2
Tello believes that the science curriculum should emphasise both content knowledge and inquiry in science and should be relevant to students' environment and lives.

Assertion 5.3
Tello believes that science is taught in schools so that students can have knowledge of the realities of the natural world and to prepare them for science-related professions.

Effective Science Teaching

Tello views teaching and learning in science as a process involving the teacher as the giver and the students as the recipient of knowledge. He likened effective science teaching to a situation whereby the teacher gives the 'precise instruction' in the classroom, moves around to ensure that no student is lagging behind in the learning process. He explained the teacher's roles:

...in such a situation the teacher's role is to give precise instruction...precise and correct information...I mean clear and detailed explanation of...in which he should move round his class to ensure that no one is being left behind...(Interview with Tello 8/2/02).

For science teaching to be effective, he believes that the teacher should give adequate instructions; adequately explain the concept with examples, demonstrate the concept, and must be able to prepare the minds of the students in order to be ready to learn the concept. He reiterated:

Being effective at any particular time means that everyone...is doing the right thing in the classroom i.e. the teacher is giving out...and the students are ready to take...it is not a situation whereby some of the students are not ready to get what the teacher is giving to them in form of knowledge. The teacher can only be said to be effective when he/she and the students are both involved in the learning process...I mean adequate explanation...with examples and demonstration...the
teacher should be able to prepare the mind of the students too, so that they can be ready and willing to learn...(Interview with Tello, 8/2/02)

He believes that science teaching and learning is most effective when the teacher has a thorough knowledge of the subject matter, plans ahead of the lesson including giving out the topic to be taught to students ahead of lesson, give the students enough opportunity to ask and answer questions during the lesson and should be able to guide them to the right answer.

...science teaching and learning is most effective when the teacher himself is very knowledgeable in the content...he must have thorough knowledge of the subject...because without such knowledge he will not be able to explain the concepts...again, he should plan ahead and give the students the topics to be taught before the lesson...The students should have the opportunity to say something...that is, to ask and answer questions... (Interview with Tello, 8/2/02)

He believes that he has been effective in his science teaching, describing what he does best in the school as explaining every detail of the subject content to his students, and that he does try to elicit their responses through questioning and one-on-one discussions with students. When asked about the effectiveness of his teaching, Tello explained:

I believe my teaching has been effective because at the end of each lesson I always observe the expressions on the faces of my students. When I feel they are happy and satisfied it gives me innate pleasure that I have done something fine...Like on a few occasions when I got to their class and I got to know through their actions that they were not quite ready...or when I felt that they might not gain much from the lesson if I began to coerce them...instead what I do is that I change the plan by giving some story to lighten up...the stories are always related to the topic that I want to teach them. For instance when I was going to teach the nervous system...I gave a story of somebody stepping on a sharp nail...asking them how they would feel if they were the victim of such an accident...then a discussion on sensory nerves opened up...everyone was trying to contribute...(Interview with Tello, 8/2/02)
Student Learning

Tello believes that his students learn best when the learning environment is conducive to learning, describing such an environment as that in which his students feel important, relaxed and encouraged to come up with ideas and ask their questions without being ignored or reprimanded. He explained:

...as I said, they are sensitive...they are always watching you, especially when you are somehow close to them. I found that they learn best when you make the learning environment conducive by relating well with them...that is, when you make them feel important and...maybe, relaxed...especially when you do not ignore them...you encourage them to come up with ideas and questions and you do not caution them when they give wrong ideas... (Interview with Tello, 8/2/02)

He believes that his openness and close relationship with the students have contributed positively to their attitude towards science. Describing the roles of the students when science teaching is most effective, he stated:

Students should ask and answer questions in class, participate fully in all class activities and be able to read ahead of lessons... For instance in a class where the teacher is demonstrating...say the concept of the physical changes... students are supposed to observe, ask questions on areas they do not understand while the teacher should be ready to give answers in precise forms...You see, because they know that I am very open...and I think they trust me...and because of my close relationship with them, their attitude...I mean many of them have changed over the years, they seem to have more interest in science now... (Survey Questionnaire, 2.13b; Interview with Tello, 8/2/02)

Students' Assessment

Tello believes that students are assessed in school in order to determine their academic achievement (i.e. how much knowledge they have acquired) and for their promotion to the next class. He is of the view that intellectual and manipulative skills are the most regularly assessed in his school. He explained:
They are assessed in order to know how much knowledge they have acquired...their ability and most of the time because they have to be promoted to the next class ...as for me...I always assess the cognitive aspect of knowledge and skills...because I believe that the skill they acquire now will be useful sometime in the future; the subject content will also enable them use the skill better... (Interview with Tello, 8/2/02).

Tello believes that assessment of students at the junior secondary levels should involve assessment of class attendance, students’ participation in practicals, projects, continuous assessment/regular tests and terminal examinations. Explaining how he assesses his students, he stated:

The methods that I use most of the time are: I grade students’ attendance in all my classes, their participation in the practical works, their continuous assessment/regular tests and also their examination which is the ultimate because they have to be promoted to the next class at the end of the school year. Concerning their skills, I group them and give them practical works or projects and I record the names of members of each group...sometimes up to 13 groups...and I assess the presentation of their projects or group works...I give scores based on how best each group presents their work... (Interview with Tello, 8/2/02)

Assertion 5.4

Tello believes that for science teaching to be effective the teacher must have good knowledge of subject matter and should be able to explain, illustrate and demonstrate the concept being taught and should possess the ability to prepare students’ minds for learning.

Assertion 5.5

Tello believes that students are to observe, ask/answer questions, participate in all activities during lessons and be able to read ahead of lessons.
Assertion 5.6
Tello holds pedagogical beliefs consistent with a knowledge transmission teaching philosophy and which are in-keeping with a traditional teaching style.

Assertion 5.7
Tello believes that students are assessed in order to know their academic achievement and for their promotion to the next class. He believes that assessment should involve regular tests, terminal examinations, projects and class attendance.

Classroom Practice

Introduction

Five of Tello’s lessons were observed during weeks four to 10 of the second term, which began on the 7th January 2002. Each lesson was preceded with a pre-observation discussion usually focused on the classroom to be used, lesson objectives and teacher’s concerns regarding the lesson. The lessons were also followed with a post-observation discussion sessions during which his impressions about the class, specific strategies employed by him in the class, and his plans for the next lesson were clarified. On the average he had 51 students in his co-educational classes. The observations of Tello’s teaching are presented in this section.

Pedagogy

Planning and organisation

Tello’s lesson plans reflected careful planning and lesson organisation based on prepared lesson notes specifying what the students should be able to do, learn or understand at the end of lessons, outlines of teaching procedures and set of activities for each lesson. The lesson notes were prepared using the State’s scheme of work for the term as a guide and curriculum content derived from the recommended textbook.
(Science Teacher's Association of Nigeria (STAN), 1984). The lesson notes seemed adequately supervised by the school system as Schools Inspectors' signatures and that of the Vice-Principal were found on some of them. The lesson note supervision and approval are probably indicative of the fact that Tello's lesson planning and organisation have to be in keeping with the school standard. The content was organised from simple to complex and appeared to be significant and worthwhile for the level of the students. Resources provided which included charts, models, metallic objects, cotton wool and petroleum oil (Lessons two, three and four) appeared to contribute positively to accomplishing the lesson's objectives. Commenting about the resources for teaching science in his school, he stated:

...this question of materials has been our problem in this school,...I think...maybe the Principal...sorry to say...does not take us seriously enough or may be it is because of lack of sufficient fund to do so...or maybe the school authority is fed-up with our requests. When we say that we don't have the necessary materials... they keep on urging us to manage...we are just trying our best, you find that these ones are not difficult to get and that is how we have been trying to get something...so that we can...at least, handle our classes... (Post observation discussion with Tello, 28/2/02)

The fifth lesson was a practical class. Unlike other lessons, no lesson plan was prepared for the practical lesson, however, the practical procedure, which was derived from the textbook, was written on the chalkboard for students as they used the insulated copper wire, battery cells, electric bulbs, and ammeters to demonstrate how electrical energy was converted to heat and light energy in groups of six or seven students. Organising and conducting the practical class appeared to be more involving for Tello as he was observed trying to provide materials for student-groups and trying to ensure that the use of materials was shared among the group members. Adequate time and structure were provided for the students to practice skills as they constructed circuits following the circuit diagram drawn on the board for them to follow in an exercise, which was basically a verification of information which the teacher had provided, and probably for 'sense-making'.

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Classroom interactions

Even though the teacher initiated the majority of interactions, student-initiated interactions (by asking questions and raising important issues) were common. Student-student interactions were not common except when they had to work in groups during the practical class. Tello frequently made use of humour and praise to arouse the students' interest and maintained a good rapport with them in all the lessons observed. Students were encouraged, their questions were clearly and simply answered and they appeared to be quite receptive to the teacher's ideas. His relationship with the students seemed to foster a positive learning environment and provide opportunity for students' learning. Tello usually opened his lessons by asking two or three questions about the concept discussed during the previous lesson and each time six to eight students would raise up their hands to respond to the questions. However, most of the time he used class questions to elicit factual information from the students.

Teaching style

Tello made use of questioning extensively coupled with regular whole-class discussions based on issues mostly raised by him. The majority of the questions appeared to be low order, recall questions requiring facts with only a few requiring students' to explain their ideas. Students' responses and ideas expressed in most of the lessons appeared to have been recalled either from their notes or from the textbook. He made an effort to explain and illustrate his concepts extensively giving various examples and provided materials, which students were familiar with, as concrete examples. For instance while explaining the concept of energy and work (lesson one), he made the students demonstrate by rolling a 'stone' ball on the ground to hit another object and elicited the students' ideas about how work is done by the stone in the process. His students were excited pulling rubber bands and releasing them to hit their benches and other objects, while he explained the concept of energy and how work is done in the process. Tello displayed a sound knowledge of the content by explaining in different ways as he tried to simplify the concept of kinetic energy:

...you see the stones as you make them to move by rolling them... or even when you throw them have energy because of their movement...you give energy to it as you roll it and it can therefore do
some work...it can knock something over... I think you saw the bottle just now...and it can hit another thing with a big sound and it can smash windows. When the moving stone does the work, the stone loses its energy and slows down or stops...when you get this...then we will compare with the energy which you give to your rubber band when you pull it...when you release them...they do some work too, because of the energy you give to them when you pull... (Lesson observation, 28/2/02).

Even though he gave most of the information to his students and demonstrated the concepts before the class most of the time, the students were also significantly involved in class activities during the majority of the lessons period ostensibly to practise the demonstrated skill (of how to release an object to produce energy of motion in this case), and to confirm information already given regarding the concept. An episode from his second lesson illustrates this.

He had explained the concepts of potential energy and chemical energy giving examples of the various sources including food, gas, petrol, wood, and describing them as forms of chemicals and the energy stored in them as chemical energy (showing a torch battery to the class as an example) and pointing out that energy was stored in the battery in the form of chemical energy. He demonstrated how the chemical energy produced heat by adding some pellets of sodium hydroxide to some water in a text-tube and told the class that heat was produced and then asked three students sitting closest to him in the front of the class to feel the text-tube (apparently to confirm that heat was produced), “What do you feel?” he asked; “This heat came from the chemical energy stored in the sodium hydroxide pellets,” he concluded (Lesson Observation, 4/3/02). He continued the class demonstration by using a circuit consisting of a battery, bulb and a key, to show how the chemical energy in the battery was changed into electrical energy, which produced heat and light. He then asked the students to do the activity themselves, using the same procedure in groups of six or seven. Explaining his aims for involving students in his teacher demonstration during the lesson, he stated:

We started on energy during the last lesson...I mean about kinds of and sources of energy and this week we are doing energy conversion...I have demonstrated how the chemical energy can produce electrical energy and heat...I did it for them and I now want them to practise how to carry out
the demonstration. I think that ...at the end of the activities...they will understand the concept more...that chemical energy can be converted to heat and can also produce light energy...when we are able to get some materials like these...we try to demonstrate...(Post Observation Interview with Tello, 4/3/02).

Tello combined the lecture and demonstration strategies employing blackboard listing as a focal point and coupled these with guided class discussions, trying to lead his students to the correct answer through quizzes, reinforcement and clear examples. Tello’s lessons appear to develop logically from the simple to the more complex in explanation and he also tended to illustrate his explanations with concrete examples. For instance, he opened a lesson (Lesson 3) by asking two questions about the previous lesson on machines and about six students raised their hands and their responses were spontaneous. He then introduced the day’s lesson “the lever” by writing it on the chalkboard, defined it, demonstrated the application by trying to use a ruler placed on a textbook on the table to raise an object. He then introduced the terms effort, load and the fulcrum, wrote the definitions on the board and led a whole-class discussion through questioning to identify the positions of the effort, load and fulcrum in the charts and diagrams (apparently drawn from the textbook) of the wheelbarrow, claw hammer and nut cracker displayed on the board. With a metre rule in his hand and pointing at the diagrams, he led a discussion of the concepts by asking a series of questions:

...The wheelbarrow is a form of what...? (a chorus mixed responses followed; some students mentioned “machine” while others mentioned “lever”). What is it used for? When it is used to carry objects, where do you apply the effort? At what point is the load on the wheelbarrow acting? Who can show the directions of the load and the effort? Who can point out the position of the fulcrum...? (Lesson Observation, 11/3/02)

Some of the lessons observed do not seem to have a link with one another because the Researcher could not observe them consecutively due to time constraints. Although student participation was minimal during Tello’s next lesson (lesson 4) on ecology, he displayed a reasonable level of integration of knowledge of content and knowledge of context as he explained and moved from one concept, terminology or definition to the next in his own words and with familiar examples drawn from the environment and
students' background in a lecture fashion. He had opened the lesson in his usual manner by asking three recall questions on his previous lesson on home appliances that use energy. About eight students raised their hands and their responses were spontaneous, probably because the appliances existed in most homes. He then introduced the concept by informing them they were going to discuss the concept of ecology and wrote the topic on the chalkboard after he had asked the students to listen and pay attention. He went on:

The place where plants and animals live is called a habitat...where you live can be described as your habitat. The biologists who study habitats i.e. such places where certain animals or plants live are referred to as ecologists. Habitats can be divided into two main groups...you have the aquatic and the terrestrial habitats...who can suggest an example of an aquatic habitat? (a chorus mixed responses of “village” “river” “stream” “well” and “pond”). Yes... these also include lakes and ponds where you have fish or frogs... (Lesson Observation, 18/4/02).

Tello never minced words, was confident and fluent in his presentation as he moved quickly to introduce the concepts of biotic and abiotic factors in habitats and again to the concept of population trying to cover as much area of content as possible within the available time. While some of the students were observed trying to write a few notes, others who apparently were unable to cope with the pace were watching, listening or leaning on their desks. He continued:

...population can be defined as a group of organism of... the same kind...say birds...or...grasshopper...that live in a habitat. I think you would have seen termites...we even have them in the school compound here...who has not seen termites moving together? (No response). For example how many frogs live in the pond behind your home... where you live...A measure of the size of population which live in a unit area is called population density... (Lesson Observation, 18/4/02).

After Tello had used the metre rule in his hand to demonstrate how the land area where organisms live can be measured and explained that organisms within a given land area constitute the population, he went on to write the formula for calculating population density on the chalkboard.
we shall practice with this example... you have to be able to calculate the population density of say... the grasshoppers that live within an area of the field... who can define the terms: population and population density? (Two students responded, one of them reading the definition of population from his notes)... (Lesson Observation, 18/4/02).

He had hardly finished writing the assignment in which he gave the names of some organisms such as ants, hawks and grass plants and their respective population sizes and areas covered by their habitats (in cm² and m²) and asked the students to calculate the population density using the formula which he had written on the board, when the bell rang signalling the change of lesson. Observation of Tello’s lesson plan for the lesson just described revealed that Tello had written under the evaluation subheading that the lesson “Shall be evaluated based on questions and answers on the concepts,” but he neither asked any questions at the end of the lesson nor recapped the main points because of time constraints.

**Assertion 5.8**
Tello attempts to cover a large amount of content within the available time and his students are not adequately involved in meaningful learning activities in most of the lessons.

In the last lesson observed, Tello conducted a practical class (Lesson 5), which was held in the laboratory. Unlike other lessons, there was no lesson plan prepared for the practical class except for the practical procedure, which he had written on a sheet of paper and subsequently copied on the chalkboard for students to follow for the practical investigation. He also gave a sample worksheet on the board and asked the students to rule their notes accordingly for recording the procedures, observations and inferences. He moved from one student group to another helping to ensure that the students had the correct circuit connection using the batteries, bulbs, keys and the ammeters as they demonstrated the concept of energy conversion. After the battery was connected to the lamp bulb in the circuit, the bulb was observed to glow brightly giving out light and the lamp became hot indicating the conversion of electrical energy to heat and light energy. The practical activity was apparently aimed at confirming facts stated in the textbook, was quite active and
involved students group work and hands-on activities and was concluded by asking the students to hand-in their practical notes according to their groups at the end of the double-period.

Overall, his lessons were mostly teacher-directed and didactic, largely dominated by telling, questioning and were based on knowledge of facts about science.

**Assertion 5.9**
Tello's teaching style is characterised by teacher-centred, didactic activities involving explaining, demonstrating, questioning and giving notes to students and based on knowledge of facts in science.

**Assertion 5.10**
Tello's beliefs about the nature of science and his knowledge transmission teaching philosophy manifested in his teaching style dominated by teacher-talk and emphasis on facts in science.

**Assertion 5.11**
Tello's good rapport with his students helps maintain their interest and engagement in the lessons.

**Teacher's reflections on practice**

Tello exhibited familiarity with the students and their home environment as he outlined the problems being faced by some of them. He believes that most of them had problems of poor attitude toward science and lack adequate encouragement from their homes. When asked about his goals for his students, he explained:

Well...I want them to develop interest in science so that they can do well in their final JSS 3 examinations...you see, I have gained a lot of experience with these students...and I, ...sometimes, feel better about myself teaching them...because I face many challenges in trying to help them...just to continue to encourage them to be actively engaged in
studying science... because you see... many of them have problems... home problems, self-esteem problems that often get in the way of their learning... many of them do not have any help outside the classroom... However, they still get excited when you expose them to new things in science...(Interview with Tello, 8/2/02)

Tello showed contentment with the way most of the classes went. He believes that, although facilities for science teaching were not adequate, he has been able to provide what he could to keep his lessons going. When asked if he had any problems teaching the classes, he stated:

Well, I... normally have this problem of lack of teaching materials... but all the same, I try to provide what I can... just to make the students feel happy as they learn...(Post Observation Discussion with Tello, 28/2/02)

He purposely tried to maintain a good rapport with the students believing that his closeness with them had an impact on their attitude towards science. When asked if he noticed any learning problems among the students, he stated:

Indeed, there are some problems... you see; some of them don't really have interest in learning science but if they like you... I mean the way you teach and relate with them... they tend to show more interest in science. But if another teacher whose teaching they find difficult is made to handle your class... maybe for two weeks or a term... you will find out that they will begin to run away from science lessons... (Post Observation Discussion with Tello, 28/2/02)

He believes that most of the students understand his teaching, and that he employs the best possible strategies given the situation of his school and the type of students he has to cope with. He explained:

I think many of them actually follow the lesson... I think this JSS 3 class is good... they do well most of the time in their tests and exams... I mean those of them that are serious... you can see that some of them are not serious to learn science. It's like we are just trying to encourage them... that is why I use these methods... (Post Observation Discussion with Tello, 28/2/02)
Tello showed a strong belief that explaining every detail of science concepts with examples, charts, diagrams or specimens enhances students' learning rather than providing them with opportunities to find out things on their own or make sense of what is being taught.

Even though Tello expressed concern about insufficient teaching facilities, his teaching style appears to be more grounded in his belief that the teacher has to explain every detail of the concept being taught while the students should listen attentively to the explanations and illustrations and then copy into their notes. He is of the view that students learn best when concepts are thoroughly explained and illustrated using various objects and examples. He tries to get objects from the environment to enhance his explanation believing that viewing the objects will enhance his students learning.

**Assertion 5.12**

Tello's classroom practice appears to be more grounded in his beliefs about teaching and about students' learning rather than on the constraints posed by school factors like large class or insufficient facilities.

**Teacher's reflections on factors which limit effectiveness**

Tello identified three major factors, which limit the effectiveness of his science teaching. They are lack of textbooks for his students, inadequate science equipment and lack of well-qualified teachers for science teaching.

Tello is of the opinion that the problems would be alleviated if the Government would provide enough funds for the education sector so that the Local Education Districts (LED) can support science authors to write science textbooks, which can be made available at a subsidised cost to the students. He is of the view that the LED should encourage the organised private sector to sponsor large-scale production of science equipments that can be made available to the schools and that government should provide adequate incentives and job motivation for science teachers. He is of the
opinion that this will help retain those in the service and attract more to the teaching profession. Explaining the staffing problem, he said:

Inadequate manpower is one of our problems...you see... in the past three years I have had to help teach further Maths...if there was no manpower problem that would not happen...I don’t know if you are conversant with the statistics as of now... our universities turn out more of arts and social science graduates than science graduates... those are the things affecting us; that is the reason those who did science as minors are being asked to teach subjects like physics for example. We are really being over-stretched... (Interview with Tello, 28/2/02)

Overview of Teacher’s Practices in terms of Pedagogical Content Knowledge

Cochran, DeRuiter, and King (1993) in their revision of the Shulman’s original model of pedagogical content knowledge (Shulman 1986, 1987) described a model of pedagogical content knowledge that comprised four components of teacher’s knowledge. These include teacher’s subject-matter knowledge; pedagogical knowledge; knowledge of students’ abilities and learning strategies; and knowledge of the social, cultural and physical environment in which students are asked to learn (see conceptual framework). Veal (1998) refers to teacher’s knowledge of these components as attributes of PCK. Tello’s classroom practices are analysed in this section in relation to these components or attributes of teachers’ understanding, which contribute to the integrated understanding referred to as pedagogical content knowledge (PCK). An overview of Tello’s practices have been undertaken in order to focus on the components or attributes of PCK that manifested in his lesson preparation and teaching.

Lesson Preparation and Organisation

Even though Tello’s PCK cannot be regarded as fully developed in several respects, it reflected many attributes or components that can be portrayed as aspects of a well developed PCK as described by Cochran et al.’s model (figure 1). For example, his PCK in relation to lesson note preparation and lesson organisation reflected accurate knowledge of content. Tello was specific about what his students should be able to learn at the end of each lesson. He organised the lesson contents in his lesson plans
from simple to complex, designed a set of learning and teaching activities for particular lessons (lessons one to five), indicated the teaching resources to be used (e.g. charts, models, metallic objects – Lesson two and three) which were relevant to the lesson topics and to the level of his students. His lesson notes also incorporated sets of specific objectives which were to be achieved at specific levels at the end of each lesson. The set of procedures, teacher and student activities, and assessment questions were tailored towards achieving his set of objectives. There were no content errors visible to this Researcher in the lesson notes. This aspect of Tello’s PCK reflected not only knowledge of content and its organisation for student learning, but also knowledge of how students learn.

Teaching Behaviour

Tello’s knowledge transmission beliefs seemed to have influenced his PCK in relation to what and how content should be presented for students’ learning. Because of his beliefs about learning, he did not perceive a role for himself in mediating the construction of meaning and understanding by his students. From the perspective of the roles he might have enacted as a mediator of understanding his PCK can be regarded as quite limited or yet to develop significantly. However, from the traditional knowledge transmission perspective his PCK seemed fairly adequate for certain specific roles he enacted while teaching.

Tello’s teaching style was predominantly a teacher-centred lecture method in which teacher-led class discussions and questioning were frequently employed coupled with an encouraging sense of humour and good rapport. These teaching strategies seemed to have been underpinned by his pedagogical philosophy that is transmission oriented. He reiterated his beliefs while expressing his views about effective science teaching:

...being effective... means doing the right thing in the classroom, i.e. the teacher is giving knowledge...to the students and the students are ready to take... (Interview with Tello, 8/02/02).

Even though he gave most of the information to his students, the information was correct and was simplified in multiple ways for students understanding. The
information was accurate and carefully organised towards achieving his lesson objective. Moreover, even though the objectives were mainly to reinforce the concepts, corroborate or confirm information already given in the class, he did demonstrate concepts before his class and involve his students in class activities. For example, during his first lesson he involved the students in demonstrating the rolling of a “stone” ball on the ground to hit another object and elicited the students’ ideas about how work is done by the stone in the process. He also involved his students in pulling rubber bands and releasing them to hit their benches and other objects. Tello tried to translate his understanding of energy and work in ways that students can understand as he tried to simplify the concept of kinetic energy and work:

You see, the stones as you make them to move by rolling them... or even when you throw them, have energy because of their movement... you give energy to it as you roll it and it can therefore do some work... can knock something over... I think you saw the bottle knocked over just now... And it can hit other things with a big sound and it can smash windows. When the moving stone does the work, it loses its energy and slows down or stops... (Lesson Observation, 28/2/02).

Tello was probably conscious of the potential difficulties the students might have in understanding the concept he was teaching and he decided to simplify the way he did and used “local” examples which students are familiar with (because children from this part of Africa play a lot with stones). He was probably integrating his knowledge of content, his understanding of how students should learn the concept of energy and work with his understanding of context (students’ background) in this lesson.

Tello’s PCK also reflected the attributes of adequate content knowledge and that of general pedagogy during his second lesson observed. He combined the lecture and demonstration strategies, listed main points on the chalkboard and coupled this with guided class discussions, trying to lead the students to the correct answer through quizzes and clear examples.

The second lesson was on ‘energy conversion.’ Even though he did not provide enough opportunity for the students to make meanings by themselves or make their views known about what they were learning, Tello seemed to be sure of what he
wanted the students to know. He was also sure of the teaching procedure (from knowledge transmission point of view) that would bring about the student learning. His ability to relate the concept of energy from different sources – food, wood, gas and so on with energy stored in the battery and light energy is an important aspect of his PCK. He demonstrated this when he explained the various sources of energy. He had explained that energy stored in food, gas, wood, battery or chemicals like sodium hydroxide was capable of producing heat or light and demonstrated this by adding sodium hydroxide pellets into water in a test-tube and asked some students to feel the heat produced. "What do you feel?" he asked; "This heat came from the chemical energy stored in the sodium hydroxide," he concluded. (Lesson observation, 4/3/02).

He further demonstrated or reinforced the concept by using a circuit connection to show that chemical energy stored in the battery could produce heat and light. The circuit consisted of a battery, bulb and a key to show how the chemical energy in the battery was changed into electrical energy which produced heat and light. He then organised the students to carry out the activity in groups of six or seven following his prescribed procedure. He also assisted the student groups in the circuit connections.

He explained why he involved the students in the demonstration:

...I have demonstrated how the chemical energy can produce electrical energy and heat... I did it for them and I now want them to practice how to carry out the demonstration. I think that... at the end of the activities, they will understand the concept more... (Post Observations Interview with Tello, 4/3/02)

Tello appeared fluent in scientific terminologies and was able to simplify and translate scientific definitions in several ways as he tried to make his students understand and grasp the meaning of scientific terms. He demonstrated these abilities during his lesson on "the lever." (Lesson three). He had provided a well-labelled diagram of the wheelbarrow, claw hammer, and nutcracker and so on as examples of the lever on a chart, which he displayed in the class. He defined the term 'lever' and explained that it was a form of simple machine. He demonstrated its application by using a meter rule placed on a textbook to raise another object from the ground. He tried to explain that the principle of lever was applicable in the wheelbarrow, claw hammer, and in the nutcracker, led a whole-class discussion through questioning to identify the positions of
the effort, load and the fulcrum when the equipments are in use illustrating with each of the displayed diagrams. For example, he had prompted the class by asking the leading questions:

...What is it (i.e. the wheelbarrow) used for? When it is used to carry objects, where do you apply the effort? At what point is the load on the wheelbarrow acting? Who can show the direction of the load and effort? Who can point out the position of the fulcrum? (Lesson Observation, 11/3/02).

His reasonable understanding of the relationship among topics and some ability to make connections with other content areas in some of the lessons observed suggest an attribute of adequate understanding of lesson topics. Tello was never observed to make evasive responses to students’ questions and misconceptions. For instance, he had asked a question that attracted mixed responses probably because it was not well structured, during third lesson observed: “The wheelbarrow is a form of what?” While some students mentioned “machine” others mentioned “lever” in their responses. Tello quickly clarified the point that they were all correct but that he was referring to the lever because the lever is one form (class) of simple machines.

Tello’s belief that science “is about concrete things in nature” seemed to inform his choice of examples in most of his lessons. He drew his examples from the students’ environment; he tried to relate the concept being taught to the students’ lives. This was demonstrated during his short review as he introduced a lesson (lesson 4). He had asked a question based on his previous lesson on appliances that use energy. The students responded by mentioning appliances like the pressing iron, radio sets, electric heater and so on, which use energy in their homes. Again, he referred to the students’ home, ponds, and streams around the school as habitats. He stated: “where you live can be described as your habitat... these also includes these lakes and ponds where you have fish or frogs.” (Lesson observation, 18/4/02).

Even though student participation was minimal, he gave accurate information about the concepts, the explanations were logical and usually from simple to complex. He seemed to have integrated his understanding of content (by giving accurate information) with his knowledge of context (by drawing examples from his classroom environment) and
his understanding of how students learn (giving detailed explanation in a lecture fashion and using concrete objects) during his lesson of ecology (lesson 4).

Because of his beliefs about student learning, Tello assigns little responsibility to students as he described their roles in an effective classroom and this appears to underpin his PCK. This is probably why his emphasis was on teaching rather than on student learning. Again, this might be probably why an attribute of knowledge of student learning did not reflect appreciably in his PCK. He had said:

...in an effective classroom, students are supposed to listen...in a quiet environment...for instance in a class where the teacher is explaining and demonstrating say the concept of physical changes...Students are supposed to listen, observe, ask questions on the areas they do not understand while the teacher should be ready to give the answer in precise form... (Survey Questionnaire, 2.13).

Because of his beliefs he did not involve his students substantively during his lessons observed; class participation was minimal, neither did he allow them to make sense of their own of the activities they were engaged in during most of the lessons. Tello’s concern was to progress through the content of each lesson, interacting with the students to the extent that they can grasp the knowledge of facts about science being provided for them, and ensuring that he completed most of the work planned for the lesson. The main goal of the lessons was to cover as much areas of content as possible within the time available. For instance, Tello did not appear to have given enough time to treat the concept of habitat before moving to the concepts of population and population density within the time of one period (Lesson 4). Knowledge of current practices in which students’ prior understanding is considered to determine the extent to which they make sense of new learning, appeared not to have been given priority or yet to be fully developed. His classroom practices reflected a general PCK associated with control and management of classroom and discipline.

Although Tello endeavoured to model good science teaching by providing multiple explanations and simplifying the concepts for students understanding, he did not require students to produce oral or written texts to make their extant knowledge known; there was no effort to ascertain whether or not some students had misconceptions about
energy and work, the lever or the concept of habitat that he taught. Because of his beliefs he did not seem to consider the need to examine the ideas that students brought with them to the class.

Tello did integrate or bring together some PCK attributes like knowledge of science content, knowledge of context and knowledge of general pedagogy; however his traditional teaching strategies did not reflect a considerable development and complete integration of these attributes. Veal (1998) asserts that effective teaching represents an integration of several PCK attributes. The PCK attribute or component of knowledge of student learning (from the constructivist perspective) did not reflect appreciably in Tello's classroom practice or is yet to be adequately developed.

Summary

Tello is a 35-year-old science teacher with 10 years of teaching experience, four of which were in his present school. He holds a bachelor degree in science and a postgraduate diploma in education. His current involvement in teaching integrated science at the Junior Secondary classes two and three is 26 periods per week, six of which are assigned to three double-periods of practical classes.

The analysis of Tello's questionnaire responses, interviews and lesson observations indicate that Tello believes that science is the study of natural things or phenomena in the natural world, that science is a collection of facts about things in nature and that though scientific theories may be revised when new understandings are generated, scientific knowledge does not usually change. He believes that the science curriculum should emphasise both content knowledge and inquiry in science.

Although Tello believes that the Lagos State's Integrated Science curriculum is comprehensive, relevant enough to students' needs, and has achievable objectives, he views the document as neither current nor flexible enough i.e. the curriculum prescribes the teaching methods to be used and does not enable him apply various teaching methods of his choice. Tello believes in the knowledge transmission pedagogy, that for science teaching to be effective, the teacher should have good knowledge of the subject matter and should be able to adequately explain, demonstrate the concept and possess the ability to prepare students' minds for learning. Tello believes that students learn
best in an atmosphere of good rapport, when they can freely express their ideas and are adequately encouraged. He believes that students are assessed in schools in order to determine their academic achievements and considerations for their promotion to the next class. He is of the opinion that assessment at the JSS level should involve terminal examinations, regular class tests, projects, practicals and class attendance.

Tello's beliefs about absolute facts in science and his transmission-oriented philosophy are reflected significantly in his teaching style which was characterised by teacher-directed, teacher-dominated, didactic activities involving explaining, demonstrating, questioning and giving notes to students and emphasis on knowledge of 'facts' in science.

For science teaching to be effective, he believes that the teacher should plan lessons well ahead of time, have good knowledge of subject matter, and allow students ask questions. He holds the view that effective science teaching and learning is a situation where the teacher gives "precise" instructions, adequately explains and demonstrates his points giving examples, and makes the concept as real as possible to the students. Tello believes that students should take part in lesson; ask questions, participate in group activities, and take notes. Tello seems comfortable with his instructional methodology, describing what he does best in his teaching as explaining every detail of the concept, encouraging students to ask questions, responding to their questions and counselling them.

Tello's design of lessons reflected careful planning and organization based on prepared lesson notes with set objectives. Resources used contributed to accomplishing the set objectives of the lessons. The majority of the interactions came from the teacher to the students; student initiated interactions were also common; however, students rarely interacted among themselves except on few occasions where they had to do group activities. Students were adequately encouraged, their questions were answered clearly and simply and they seemed receptive to teacher's ideas. Tello elicited factual information most of the time from the students and they responded with factual information. Tello made use of questioning strategy extensively but the questions were mostly lower order, recall questions requiring facts, or procedures derived from the textbooks. His PCK appeared to reflect an adequate knowledge of science content; quite confident, presented accurate information, never made reference to the textbooks or his
lesson notes in class except when giving notes to students. In most of the classes science content appeared to have been taught in isolation with little attempt to make it investigative.

Because of his beliefs he did not involve his student substantively during his lessons observed; class participation was minimal, neither did he allow them to make sense of their own of the activities they were engaged in during some of the lessons. Although Tello endeavoured to model good science teaching by providing multiple explanations and simplifying the concepts for students understanding, he did not require students to produce oral or written texts to make their extant knowledge known; there was no effort to ascertain whether or not some students had misconceptions about the concepts that he taught.

Tello did integrate or bring together some PCK attributes like knowledge of science content, knowledge of context and knowledge of general pedagogy; however his traditional teaching strategies did not reflect a science PCK consistent with the notion of effective teaching and learning in science as outlined in chapter 2. The PCK attribute or component of knowledge of students’ learning (from the constructivist perspective) did not reflect appreciably in Tello’s classroom practice.
CHAPTER 6: CASE STUDY 2

Introduction

This Chapter presents the second case study, which involved Ms Angy. The case study was compiled from data gathered by interviews, lesson observations and analysis of curriculum documents. The case study is presented in five major parts. Presented first is her profile as a teacher followed by the context of science teaching in her school. The third part outlines the teacher's pedagogical beliefs while the fourth part presents her teaching practices. The fifth part presents an overview of her practices in terms of pedagogical content knowledge (PCK). The Chapter concludes with a summary.

Teacher's Profile

Angy is a 37-year-old female science teacher in an urban school located within a school village comprising four secondary schools in the Lagos metropolis. She had been teaching for six years, all of which were in her present school. She holds a Nigerian National Certificate in Education, a bachelor degree in science education and a master degree in education. Her current major responsibility is to teach science at the junior secondary level consistent with the Local Education District and school expectations, which meet the needs of all the students (Interview with the Vice Principal, 8/3/02). Angy is directly responsible to the head of science department who, in turn, is responsible to the Vice Principal (Academics). She is one of two teachers assigned to teach Integrated Science at the junior secondary level and she is mainly involved in teaching years two and three classes (i.e. 14 and 15 year olds). Her current teaching load is 36 periods per week, eight of which are assigned to four double-periods of practical classes. Angy is very well respected by her colleagues and students.

Angy's goals are to develop her students' interest in science subjects, promote their confidence, and make them literate in science. She believes that scientific literacy helps people live better lives (Interview with Angy, 8/3/02). Angy views science as a dynamic process involving inquiry. She believes that she has been effective in her science teaching because she tries to emphasise science processes and skills particularly those mentioned in the scheme of work (Survey Questionnaire 2.4).
Angy’s school is an urban secondary school located in the Lagos State of Nigeria. It is a coeducational school with a population of about 4,500 students. Integrated Science is taught as a compulsory subject at the junior secondary level. Each year level has between four and five streams. The school has separate science laboratories for each of the science subjects: Chemistry, Physics, Biology, Agricultural Science and Integrated Science. The Integrated Science laboratory is typical of those found in Lagos State schools. Bottles of mineral acids and bases, flasks, microscopes, lenses, models and charts were observed in the laboratory. Equipment like Bunsen burners, hand lenses, microscopes, ammeters, glass prisms seen in the laboratory seemed well maintained but relatively few in number considering the number of students in Angy’s classes. Even though students were brought into the laboratory only when they had practical classes, teachers were free to take models, charts and other materials out of the laboratory for use in their lessons in other classrooms. The classrooms were quite adequate for learning; seats and desks were sufficient for the number of students, every student was comfortably seated in most of the classes observed. Although the school had an adequate range of laboratory equipment, the amount of equipment was inadequate for the number of students in each class.

Integrated Science is taught in the school based on the content and guidelines in the National Integrated Science Curriculum for JSS 1-3 and the Lagos State’s Unified Scheme of Work for Integrated Science (Federal Ministry of Education, 1980; Lagos State Ministry of Education, 2001/2002) which itemised the science content to be covered each week over the three school terms in the academic calendar. Angy had between 50 and 54 students in each of the JSS 2 and 3 classes she taught. The materials she used frequently for her teaching included the teacher’s diary, lesson notes, continuous assessment record book (mark book), a copy of the scheme of work, and the weekly timetable. Although the school appeared adequately equipped for science teaching at the junior secondary level the large number (between 50 and 54) of students in Angy’s classes places enormous strain on the resources.
Teacher's Views

The Nature of Science

Angy believes that knowledge of science changes over time, that science is a way of investigating and developing understanding about the natural world (Survey Questionnaire, 3.7, 3.9), and that science has to do with inquiry about how to improve society. She believes that science is a process for doing things in a way that makes it more beneficial to people and society and that knowledge of science is applied to solve daily problems in order to live better lives. Explaining her view regarding the nature of science, she stated:

...Well, as a teacher, I see science also as a dynamic process; not limited to the four walls of the classroom, knowledge of which we apply to solve our daily problems...For instance when you want to wash a cloth...may be your cloth is stained with oil...and you apply kerosene and it gets removed...that is a scientific process. So, science can be seen as everyday activity, which tends to make things easier...we use knowledge of science to solve problems and we apply it in our daily activities...to live better lives... (Interview with Angy, 8/3/02).

She believes that science is taught in the school in order to make students literate in science, to create awareness, to help children understand what is happening in their environment, and to prepare them for science-related careers. Explaining her reasons for science teaching in the junior secondary years, she stated:

We teach science to these students in order to make them literate in science...to prepare them so that they can be aware of what is happening in their environment...you see they have to be able to know that even the cooking which they do in the kitchen is a scientific process. For instance if a child is aware that something is harmful...or can cause health hazard...he/she will try to avoid it...Again they have to have knowledge of science because of the future professions they might want to go into...say if they want to become doctors, engineers...even if they want
to become science teachers, they will not be able to do so without the knowledge of science... (Interview with Angy, 8/3/02).

Angy believes that the science curriculum should emphasise both content knowledge and methods of inquiry (Survey Questionnaire, 5.1, 5.2).

**Assertion 6.1**

Angy believes that science is a process of doing (producing) things, and a process of investigating and developing understanding about the natural world. She views scientific knowledge as dynamic and useful for solving problems.

**Assertion 6.2**

Angy believes that science is taught in order to make students literate in science, create awareness about what happens in the environment and prepare individuals for science related professions.

**Effective Science Teaching**

Angy views effective teaching and learning in science as a situation where both the teacher and students are actively engaged in the teaching-learning activities. For science teaching to be effective, she believes that the class should be of manageable size and that enough teaching resources should be provided. Explaining the conditions she feels are necessary for effective science teaching and learning she emphasised:

...the classroom have to be manageable...it should not be too large... for effective monitoring and there must be enough materials too...for students to be able to carry out hands-on activities because in science we believe in teaching and learning of skills. Enough resources must be there to make them comfortable so that they can learn better... (Interview with Angy, 8/3/02).

She believes that science teaching is effective when the teacher is able to explain the concept he/she wants the student to learn, demonstrate the skills involved, guide the students to perform hands-on activities and encourage them to ask questions and
practice skills on their own (Survey Questionnaire 2.13). In describing the role of students when science teaching is effective, she said:

The first thing is for students to listen to explanations and instructions given by the teacher...because if they do not, they would not know exactly what to do...they should follow instructions regarding skills and participate fully...they should be able to demonstrate the skills required for the lesson...and they have to ask questions on any aspect of the lesson... (Survey Questionnaire, 2.13b).

She believes that science teaching can only be effective if students learn science by doing activities, that there should be enough resources for hands-on learning activities and that the teacher should also be resourceful enough to be able to improvise some of the materials or get them from the environment making use of the students if possible. When asked to comment about the available materials for science teaching in her school, she explains:

...I know that we lack these materials...if we don’t talk about it the school will think that we are ok with the ones we have...they are not sufficient...sometimes we use them up and most of the time... they are not replaced. But we have to be able to get something too...sometimes we don’t really use only chemicals or reagents...What of insects, leaves, flowers...sometime toads or lizards or fish? ...This environment contains a lot of these things...it’s difficult but I know how to get many of them...I use my students sometimes and they are always happy... (Interview with Angy, 8/3/02).

She believes that her teaching has been effective because her students' achievements have been above average judging from their performances in both practical and written examinations. Reflecting on her students’ achievement, she explained:

We usually carry out practicals...for instance; we have been able to do both volumetric and qualitative analysis a number of times. As you will soon find out in their class, they already know how to handle most of the things; they can manipulate pipettes and burettes, they can make efforts to detect cations and anions present in salts given to them...because I try to make them do those things over time... just to improve their skills... (Interview with Angy, 8/3/02).
She however expressed regret that she has not had the opportunity to attend seminars and workshops for three years in order to update her knowledge about current practices about science teaching. She believes that things are always changing in the world of science, that she did not feel that she was still abreast with current issues in science teaching. She reiterates:

...I haven’t had the opportunity to attend any seminar or workshop for three years... I have not been able to update my knowledge, you know that things are always changing. You see... I cannot boast that I am current...I can’t. Other teaching methods are probably being discovered by which science can be taught to students more effectively. (Interview with Angy, 8/3/02).

Angy believes that teaching and learning of skills are important in science. She is of the view that for science teaching to be effective, the teacher must be able to explain the concepts being taught, demonstrate the skills involved, guide the students to perform hands-on activities and practice skills on their own and encourage students to ask questions. She holds the view that for a teacher to be effective, he/she must be resourceful by being able to improvise or source teaching materials from the environment. Angy believes that students should listen to instructions so as to be able to understand what to do in the class and participate fully in class activities by being involved in hands-on activities, demonstrate and practice skills and ask questions.

Student Learning

Angy believes that her students learn best when she provides the materials they need to work with during the lesson. She explained that the students tend to lack initiative to do things on their own unless prompted, probably because of lack of textbooks in the library or because materials could not go round most of the time, but that she tried to keep them busy by improvising materials and making sure that the class had materials to work with during lessons. She believes that her students learn best when they are given the necessary encouragement to be part of the lesson, when they feel free to interact with each other and with her, when they are kept busy doing class assignments or hands-on activities and are adequately supervised. Angy seemed to regard students’ background and level of development as factors in their learning. Describing how she tries to help them learn, she states:
...because they are still young, I think they need thorough supervision...you have to know them by their names and maintain good rapport too...they may be expecting you to give notes because they can’t do much on their own...but that is not the most important thing to do...you have to give out the work to do...and you go round them, encourage all of them to participate, even when they have to work in groups...try to be in their midst most of the time...then you will discover that they are not as bad...(Interview with Angy, 8/3/02)

She believes that given the opportunity, the students would prefer to learn by receiving all the information from the teacher because they tend to view the teacher as the 'source of knowledge' or the custodian of whatever they need to pass their examinations. Angy does not seem to believe that giving information to students or telling is good teaching. She explained:

They want to learn by receiving every information from the teacher...they see him/her as the author of knowledge...that they are learning...so, most of the time they prefer the teacher to give them all the information regarding all that they need to learn... and when you ask them to go and study certain things on their own... they tend to get confused... probably this is because they don’t have reading materials anyway... However, as their teachers... I think that some of us know what to do... because giving them only information will not help much; we are to teach them... (Interview with Angy, 8/3/02).

She believes that engaging students in class activities makes them develop interest in science subjects and was optimistic that most of her present JSS 3 students were going to be science students on graduating to the senior secondary school. Angy was apparently unhappy that some science teachers were not doing enough to help students develop a positive attitude towards science. She explained:

If you sample opinions of my JSS 3 students as we are discussing now, you will find out that they prefer science to other subjects. I am saying this because...I, myself...I do so most of the time...and they also come to me to say that they don’t want to be classified as art students when their final result is released because we use their results to determine
where they belong...it's either Science or Arts. You see...they even suggest what to do sometimes...I mean those experiments which they did in JSS 1...probably they did not follow...they want us to repeat them in my class...sometime we do such thing and some time I tell them we've got a lot to do in our scheme of work and I promise them that we will do such experiments latter...You see sir...if every teacher tries to do the same thing...I mean if we plan together to do these things instead of complaining about facilities and all that...most of the time...I really believe that some of us are not doing enough...(Interview with Angy, 8/3/02).

Angy believes that the science curriculum should be relevant to students' environment and lives, that the Lagos State Integrated Science curriculum though comprehensive, it is not quite current or relevant to students' needs (Survey Questionnaire, 5.5).

Student Assessment

Angy believes that students are assessed in school in order to test their academic achievement, whether or not they comprehend what they are being taught in school, so that the school can keep records of every student for the purposes of report cards and their promotion to the next class. She is of the view that students' knowledge, skills and attitudes should be assessed in schools (Survey Questionnaire, 2.15). Explaining what she called 'common' assessment practices in the school, she explained:

...The LED or the government says that we should carry out continuous assessment tests and this is stated in our scheme of work...at least...that is why we are provided with the assessment book for recording them...We have to do at least three continuous assessment tests in a term...before the terminal examination comes up. Because of that...some people just want to satisfy the rule...they just do three short tests...to fill the assessment book. I think government should do the right thing...because assessment...as I was taught, is it not part of our teaching? I think it should not be limited... (Interview with Angy, 8/3/02)

Angy believes that assessment should not be limited or stereotyped; she feels that students can be assessed in various ways provided the teacher is of the opinion that it
contributes to his/her teaching or students' learning. Describing how she assesses her students, she explained:

I do assess my students as many times as possible and in different ways...sometimes I sum up the results of many class tests or quizzes and record them in the assessment book. I assess their knowledge by giving them written examinations, quizzes...then, sometimes I assess their skills...how they manipulate apparatus...because I usually organise practicals for them and...sometimes group projects...and I give marks for good behaviour...for instance neatness and their dressing and the way they enter the class or the lab...some time some of them rush into the lab...and I tell them that one mark is taken from their score for behaving in such a manner...and many of them have become well behaved as a result...(Interview with Angy, 8/3/02).

Angy does not seem satisfied with assessment practices in her school; she is of the view that assessment should not be limited particularly to three short tests in a school term. Angy believes that students should be assessed in various ways provided it contributes to effective science teaching and students learning.

**Assertion 6.3**

Angy believes that for science teaching to be effective both the teacher and students should be engaged in the teaching-learning activities, that the teacher should be able to explain, demonstrate skills, guide the students to perform hands-on activities and practice skills on their own, and encourage them to ask questions.

**Assertion 6.4**

Angy believes that students learn best when they feel free to interact with each other and with the teacher, ask and answer questions, learn by carrying out hands-on activities, and are adequately supervised.
Assertion 6.5

Angy believes that students are assessed in order to know their academic achievement, for reporting purposes, and for their promotion to the next class. She believes that students should be assessed in various ways provided it contributes to teaching and learning and should involve the various aspects of learning i.e. knowledge, skills and attitudes.

Classroom Practice

Introduction

Five of Angy's lessons were observed during weeks two to nine of the third term, which began on April 8, 2002. Each lesson observed was preceded with a pre-observation discussion usually focused on the teacher's preparations for the lesson, lesson objectives and expectations from the lesson. After each observation, a post observation discussion also took place during which the teacher's impressions about the lesson, clarifications regarding methods employed and plans for the next lesson were sought. Angy had between 50 and 54 students in each of the lessons observed. The results of observations of Angy's lessons are presented in this section.

Pedagogy

Planning and organisation of lesson

Angy's lessons were based on lesson plans (also referred to as lesson notes) which specified lesson objectives, summary of content for the particular lesson, outlines of teaching procedures, set of activities to be performed during the lesson and evaluation procedures. The lesson notes were based on the State's scheme of work, which in turn, was derived from the National Curriculum for Junior Secondary Schools (Federal Ministry of Education (FME), 1980). The scheme of work contains the summary of curriculum content to be taught in each of the three terms in a year thus serving as a guide for weekly content selection for the teachers. Her lesson contents were derived
from the recommended textbook for Integrated Science (STAN, 1984), and appeared logically organised from the simple to complex, appeared worthwhile and appropriate for the level of her students. The lesson plan seemed adequately supervised by other officers of the school system as signatures of the Vice-Principal and school inspectors were found on some of them. She provided various resources including charts, models, and various objects from the school environment, which appeared to contribute significantly to accomplishing her lesson objectives.

**Interactions**

Even though Angy initiated most of the interactions in the class, student-initiated interactions were very common. She tried to create a social environment in most of her classes in which the students freely interacted among themselves, asking and answering questions, contributing ideas to class discussions and engaging in collaborative activities. She frequently started class discussions and used praise and a sense of humour to encourage and arouse students' interest. The students actively participated in most of the class discussions. For instance, she had opened a lesson based on iron and rust by eliciting information from the students regarding the location of an iron and steel factory in Nigeria. She had brought into the class some iron rods, iron nails (some already rusted) and steel spoons (Lesson three). A student responded:

My dad works there; he got posted to Aladja steel works...I have been there too... they make steel and iron and... convert steel to iron...

(Lesson Observation, 22/4/02)

Another student quickly corrected him by saying that it was the other way round and the teacher carefully directed the discussion to ensure that the misconception was corrected. Ideas contributed by the students were quite numerous and the teacher played the role of a moderator most of the time summarising some of the points and writing them on the board. The students became curious when another student retorted:

"My dad is a dealer in iron rods...we sell them and they are used for building houses and... all that...but some of them ...when they stay long in the yard... they get old...then they become rusty" (Lesson Observation, 22/4/02).

Angy encouraged and valued active participation and a climate of respect for students' ideas, questions and contributions existed in most of her lessons that were observed.
She opened most of the lessons by asking some questions based on the concepts discussed during the previous lesson and each time as many as 10 students would raise their hands instantly to respond to such questions. Information elicited from students by Angy's questions required both recall and reasoning.

**Teaching style**

Angy combined her teacher-led demonstrations with student-centred teaching styles. She focused on students' participation as she tried to develop both their knowledge and skills. She appeared to pay more attention to helping students grasp the development of knowledge as a process rather than a product. She focussed some of her classroom activities and assignments on student-centred processes of inquiry. The first lesson observed was a concluding lesson on acids and bases. She had taught three other lessons with the class based on the same concept in which different aspects of the concept were discussed. Groups of students were involved in grinding different flowers in mortars and trying to extract indicators from the substance while she was supervising the entire process. Probably in an attempt to enable the Researcher to understand what was going on, she stated:

This is the last of the series of lessons we are having... on this topic, we earlier studied acids and then bases and then... we learn how to test for acids and bases in many organic substances including unripe fruits...(pointing at oranges, pawpaw and limes at the side benches) and of course these other ones we have in the lab...(pointing at inorganic acids and bases), we made use of indicators ...the ones available in the lab....We are now trying to extract our indicator from flowers and we will use it to test for acids and bases...we will test them in those things (pointing again at the fruits)...(Lesson Observation, 19/3/02)

She had provided different types of flowers including the hibiscus, crotalaria and so on from the school premises, solvents like methylate spirit, benzene and acetone, test-tubes, mortars and pestles, funnels and filter papers for the class activity. While the students were still busy extracting the pigments from the flowers, she asked them to use one or two drops of their filtrates to test for acids and bases in each of the local fruits
provided, record their observations and conclusions. She summarised by listing the ideas contributed by the students on the chalkboard.

Angy's second lesson observed was with a JSS 2 class. She said that the lesson was a concluding lesson on "nutrition and growth." She had introduced the lesson by asking three questions on the previous lesson to which five students responded and she reviewed the lesson in about two minutes. She then asked the students to bring out the materials she had asked them to bring to the class informing them that they were going to test for the presence of starch in "our food items."

After she had observed some of the items which included guinea corn, maize, cowpea, yam flour, cassava flour, dried fish, dried meat, and palm kernel and so on, she asked three students to collect mortars from the laboratory and explained that they needed to grind or crush some of the items into smaller particles to enhance their solubility in water. She demonstrated the test for starch using a powdered starch, which she had brought into the class by adding a drop of iodine solution. She provided the students with watch glasses, iodine solution and droppers and asked them to carry out the experiment using the powdered starch first and then the food items one after the other.

There were initial arguments or confusion regarding the "correct colour change" when they started to add iodine solution to their samples as many students described it in various ways: "blue", "dark blue", "blue black", "black" or "dark brown", anticipating that the teacher would give the correct description. Angy instead, asked them to describe the colour change as they saw it. She continued:

...you are to write down your findings in two columns (illustrating how to rule the columns on the chalkboard) using these headings "Food that contain starch" and 'Food that do not contain starch"...Lesson Observation, 8/4/02)

After she had supervised the students for about 20 minutes, she opened a discussion by asking an open question, "Do all plants or animals contain starch in them? Let us have your ideas with explanation..." (Lesson Observation, 8/4/02). Many of the students contributed to the discussion backing up their conclusions with their observations while she listed some of the points raised on the chalkboard. This lesson was student-centred;
she guided the students to carry out hands-on activities, leading and encouraging them
to do it and find out things on their own, in a manner consistent with her espoused
beliefs in student-centred pedagogy.

Angy tried to keep her students engaged either in class discussions or doing activities in
most of her lessons, spending time going round her class to view group activities and
listen to students' ideas. She tried to direct the focus and moderated most of the class
discussions prompting less active students to air their views and she would release
information only at the appropriate point in time. For instance, her timely response to a
student's misconception during a lesson (Lesson three) indicated a high level of
pedagogical skill. One of the students, in a class discussion, said, "When the iron rod
stayed long in my father's yard they become old and... rusty". She responded by giving
out rusted and un-rusted iron nails and rods to student-groups to observe, classify and
point out the differences. She tactically directed the discussions to focus on why iron
rusts and conditions necessary for rusting to occur. She explained:

They don't become rusty because they become old...they don't grow old
do they? They have been left...exposed to conditions that make them go
rusty...I don't want to tell you now...when we go through those
experiments (pointing to the side benches) you will find out that certain
things...conditions make iron to rust. I will only say that if iron is well
protected... it will not rust... (Lesson Observation, 22/4/02)

She illustrated how the student groups should keep nails in test tubes under different
conditions in order to find out the conditions necessary for rust to occur and she
supervised them as they carried out the activity. The first test-tube contained nails in
water and opened to the air; the second contained nails with silica gel crystals and well
corked; and the third contained nails in boiled water with layer of palm oil on top of it.
She continued:

...you are advised to label your test tubes with your group number and
have it kept in the racks in the laboratory...Go there and observe it
everyday and record your observations... and you are to continue until
we meet again on Friday...and you are expected to come up with the
conditions necessary for rusts to occur... (Lesson Observation, 22/4/02)
The fourth lesson observed was a practical class. Unlike the other lessons, the practical lesson was much less structured since no lesson plan was specifically prepared for it. Explaining the reason why the practical was not as structured as other lessons, she stated:

The reason is that we prepared for these set of practicals in advance...at the beginning of the term, so...we already know what to do and we work in groups most of the time and...you see, the students don’t have to do the same thing...I mean the groups...at the same time. Of course it depends on what is available...so, we do rotate the practicals among the groups. Since we emphasise scientific skills here...for example, you can see these groups using the microscope to be able to draw something...while the other one is working on spring experiment...measuring extension...and... even sometimes I ask the groups to choose the one that interests them. We do those in our scheme of work and we normally cover them during the term... (Post Observation Discussion, 10/5/02).

Organising and conducting the practical class seemed very involving for Angy as she was seen moving from one group of students to another trying to ensure that materials were shared, that everyone was participating and there was no laboratory assistant to assist her. There were about nine practical exercises prepared for the student groups to carry out on a weekly rotational basis. Each group had the opportunity of choosing the practicals they wanted to carry out first.

The practical procedures were given to the students in all the cases. Certain aspects of the practicals could be regarded as confirmatory as the practical handouts gave expected results, for example, colour change at end-points, expected type of curves, odour or colour of expected gas. There were also aspects that are investigatory in nature, for instance, a group of students counting the number of spatulas of table salt added to a quantity of water at room temperature in a beaker had just attained “a point where the solution would not dissolve any more salt.” At the next stage they were only asked to vary the experimental condition by using hot water instead. They investigated the effect of higher temperatures on solubility by using hot water at different temperatures and also made use of alum, copper (II) tetraoxosulphate (VI) in place of table salt. The group was seen busy trying to plot a graph of “number of spatula-full” required to
saturate 20cm³ of water against temperature. Questions that followed the students' investigation just described include “Is there a time where no more salt will dissolve?” “Find out the weight (roughly) of the salt that 20 cm³ of water can dissolve?” “Is the effect of warming the same for all the substances?” “What happened when the hot saturated solution cooled down?” “Briefly explain your conclusion from your graph?” (Lesson Observation, 10/5/02)

Another student group was also observed plotting a graph of angles of incidence versus angles of reflection from their tabulated readings under the headings: number of experiments, angles of incidence, and angles of reflection. The group had directed a ray of light from a ray box onto a plane mirror and measured the angles repeatedly and allowing one another to take the measurement using a protractor. Angy moved from one group to another providing assistance to the groups where necessary. At the end of the session she was seen, assisted by some students, carrying a heap of practical notes to her staff room for grading.

Angy's lesson design and organisation incorporated tasks, roles and interactions fairly consistent with inquiry in science teaching and learning and she adequately provided resources for the majority of her lessons. Angy appeared to have combined constructivist-compatible ideas with her overall teacher-directed teaching style in most of the lessons observed considering the fact that she did not readily release information, sometime allowed students to find out things by themselves and allowed them to contribute ideas (Lessons one, two, three, and four).

Examination of the contents of the practicals revealed a close relationship between them and the concepts taught in other lessons except that they were not closely linked as a result of time intervals between them. Most of the concepts and the practical activities on which they are based were taught weeks apart. Her practical lesson in which practical investigations were carried out on a rotational basis due to limited resources was capable of encouraging learning through repetitive practice of discrete skills, which is consistent with traditional knowledge transmission ideas (Jason et al, 2000). Nonetheless, the practicals have investigative ideas and activities incorporated in them making her strategy consistent with the provisions of guided enquiry in science teaching (Ajewole, 1990).
Of particular note was Angy's fifth lesson (last lesson observed), which she had with a JSS 2 class in which she displayed high levels of both content and pedagogical knowledge. The topic was food storage and her main objective was that at the end of the lesson students should be able to appreciate the need for appropriate food storage and identify various methods of doing so.

She had opened the lesson by asking about three questions based on the previous lesson to which six students responded, she did a preview lasting about two minutes and then wrote the day's topic on the board. She then began to distribute various local food items, which included potatoes, yam tubers, beans, maize, and millet to the student-groups asking them to observe and separate bad ones from the good ones, and the reasons why some of the items went bad or rotten. Her students' participation was overwhelming and she used that to open a whole-class discussion on the need for food storage and various methods of storage. She led and directed the discussion by asking leading questions, prompting students to think and reflect on their own experiences, releasing information only when it became necessary and acting as a moderator to the discussion at the same time, and tactically using her experience to pull the class back to the main point of the topic while demonstrating respect for the students' ideas.

Materials and resources provided in most of her lessons supported the instructional goals and engaged students in meaningful learning. Even though her attempts to help students articulate their ideas slowed down her content coverage, her time allocations were quite realistic. The majority of the lessons ended after she had summarised the main points and given them assignments for the next lesson.

Angy made use of questioning extensively in most of her lessons. She regularly asked questions that went beyond mere recall to probe for higher levels of understanding and usually allowed a wait-time before placing the question with a specific student. She
often followed student responses with further questions like, “Does anyone see another possibility?”, “Who has another idea?” or “Who would like to comment on Ade’s idea?”

She was able to vary her strategies making use of a combination of lecture, whole-class discussion, and inquiry-oriented approaches at different times depending on her classroom situation. She seemed quite confident, knowledgeable about science content and pedagogy; simplifying concepts in her own words, without reference to any text materials, drawing examples from students’ home and school environments, and making connections with several content areas. Her entire plans and practices seemed to reflect understanding of prerequisite relationships among topics and concepts in Integrated Science. She appeared sensitive to students’ learning problems and misconceptions as evidenced by her prompt response when a student expressed the idea that “iron rusts when it gets old.”

**Assertion 6.7**
Angy’s classroom practices are grounded in her beliefs about effective science teaching (that both the teacher and students be involved in the teaching – learning process), about student learning (that students should learn science by doing, feel free to interact during lessons) and about students’ assessment (that students be assessed often and in various ways, and that assessment should contribute to teaching and learning).

**Assertion 6.8**
Angy’s teaching style was characterised by both teacher-centred and student-centred activities involving teacher-led whole class discussions, students’ engagement in group activities in which she appeared to emphasise meaningful learning rather than covering large amounts of content.

**Assertion 6.9**
Angy developed a positive classroom climate with good rapport, and students interacted freely and confidently expressed their ideas and all of them seemed eager to participate in class activities.
Teacher’s reflections on practice

Angy showed contentment with the way most of her lessons went, given the constraints posed by school factors including large classes and insufficient science teaching resources. She felt that she had been trying the best she could to help her students become literate in science. The interest she has for her students and the teaching profession appeared to be the major motivating factors in her efforts to succeed in her duties in the school, notwithstanding the constraints. Expressing how she feels about her students learning, she explained:

These students are not to blame for anything...as far as I am concerned. Even though...some of us in this profession have made them to believe that they should just sit down...maybe copy notes in class... and that is what most of them will want to do given the opportunity...especially when they get bored...and then we complain about their attitude towards science. You see...they get more interested when they are doing something...when you try to engage them in activities, I think you saw them in the class...that some of them were really ok. Some of us go the extra mile to be able to get things...I mean for our teaching and this is why we have a lot of pressure...I think some of us are doing more than we should be doing and the school...or the authorities never appreciate this...(Post Observation Discussion, 10/5/02)

Angy did not believe that the students have peculiar learning problems apart from the problems of poor background knowledge of science and inability to acquire the necessary science textbooks. She did, however, seem to assert that some teachers are not doing enough to help the students. When asked if she noticed particular learning problems among the students, she stated:

The only problems that one can think of is...maybe about their background...some of them are from the nursery primary school background and others from public primary schools. You know that the nursery schools start to teach general science from lower classes; those from public primary schools seem to be lagging behind...I think most of them especially at the beginning...Again some of them come from very poor homes and they don’t have books to read...no encouragements from
parents also... maybe their parents are illiterates. Other problems... I think are not really that of the students... maybe they are caused by some of us teachers... (Post Observation Discussion, 28/5/02)

Angy's belief that students develop more interest and learn better when engaged in activities seemed to underpin her classroom activities. She believes that she has been effective because she makes an effort to engage students in hands-on learning activities, in meaningful learning, and tries to provide a socially supportive atmosphere in which students' interests are considered important.

...it is my belief that science can be learned by doing activities... that is why they are able to understand the concepts I teach... they interact with each other in social way... teaching one another sometimes... you see I no longer complain about their attitude... you see, as long as I carry most of them along... (Post Observation Discussion, 28/5/02).

Assertion 6.10
Angy displayed a sound and current knowledge about science teaching and student learning.

Teacher's reflections on factors which limit teaching effectiveness

Angy identified large classes, lack of appropriate textbooks and inadequate laboratory facilities as major factors, which limit or inhibit her effectiveness in science teaching (Survey Questionnaire 2.14). When asked to outline the factors, which limit her effectiveness in her science teaching, she explained:

... the number one problem is this large population in the classes... because when the class is too large there cannot be effective control and... you see, when there is no effective control teaching-learning process is inhibited, then another thing is the lack of facilities... this again has been made worse due to the large population... we don't just have enough things to teach with... This is why I use grouping of students most of the time... and I know that it's not comfortable and because... it affects their rate of
assimilation...understanding. Regarding the textbook...I think those available are the ones the teachers are using; most of the students cannot afford to have the textbooks in order to be able to read on their own... and even, there are not enough books in the school library...there may just be about three or four textbooks there in a particular subject area...and what can that do considering these number of students. When you give assignments, some of them are able to share with their friends while others are just helpless... (Interview with Angy, 8/3/02)

She observed that the chemistry aspect of their Integrated Science suffers most because they cannot replace most of the reagents, which are used up. She explained:

...another major one is the lack of reagents in our laboratory...you know...most of these reagents...or chemicals we use in the chemical science aspect of our subject particularly...you see, we use them up... they are always being consumed... and we are told that there is no fund to buy...or replace them...or maybe provision is not made for it in their budget...(Interview with Angy, 8/3/02)

Angy believes that her effectiveness would be enhanced if those problems were solved suggesting that classes should be smaller consisting of 40 students at most, that the state government should increase funding for science education and that the Parents Teacher Association (PTA) should assist the school in providing resource materials for use in the school. She explained:

To address the problems may be difficult...unless of course...you see, one way out is that we should split the classes...may be for a particular science class we can have say, class A1, A2 and so on...so that a class will not be more that 40 students at most ...Then another thing is that the government should come to the aid of the school by providing the necessary fund with which we can get those facilities that we need particularly in our lab...these facilities are very important for our work and also for our students ...because if a child is not comfortable he/she will not be able to learn...then for reading materials, I think the school should appeal to the PTA to try and make efforts to provide these resource materials for their children...because the government cannot do
all these things alone... they should at least create some time to plan for their children...(Interview with Angy, 8/3/02)

Lesson observations indicate that Angy provided materials used in her lessons from both the laboratory and the environment. She made use of the students to provide some of the teaching materials. Though there were science teaching materials/equipment in the school laboratory, they were not sufficient considering the average number of 52 students per class, even though she made her students work together in groups during hands-on activities.

Overview of Teacher’s Practices in Terms of Pedagogical Content Knowledge (PCK)

The model of pedagogical content knowledge described by Cochran, DeRuiter, and King (1993) considers teacher’s subject matter knowledge, pedagogical knowledge, knowledge of students’ abilities and learning strategies, and knowledge of context in which the learning takes place. Angy’s teaching practices are analysed in this section in relation to these attributes or components of pedagogical content knowledge.

Lesson Preparation and Organisation

Angy’s PCK reflected many attributes or components some of which she had developed to varying degrees. These attributes were exemplified in her lesson plans that reflected knowledge of content, knowledge of student learning, knowledge of general pedagogy and knowledge of context. Each of her lesson plans showed a set of specific lesson objectives, summary of selected content for the particular lesson, outlines of teaching procedure, a set of activities to be performed during the lesson, and evaluation procedure for the lesson.

There were no content errors visible to this Researcher in any of her lesson notes. She incorporated a variety of teaching strategies and developed a set of student activities for each lesson. For example, in her second lesson she had planned to have students work in groups. The activity involved a test for starch in a variety of food items which students were to bring from their homes. Angy seemed to have simplified the lesson contents to meet the level of the classes she taught. The contents were organised from simple to
complex while the teaching procedures were broken into various steps to be followed during her lessons.

She provided various resources including charts, models and various objects from the school environment which appeared to contribute significantly to accomplishing her objectives. Angy’s lesson plans suggest that she called upon her understandings of content, pedagogy, student learning and context of teaching/learning.

Classroom Behaviour

Various attributes or components of PCK were reflected in Angy’s classroom practice. Of these attributes her understanding of content, student learning and context appeared to be more prominent or more apparent in most of her lessons. This was demonstrated in her first lesson based on acids and bases. She was specific about what she wanted her students to achieve in the lesson and developed appropriate activities in order to achieve her lesson objectives. Her students had learnt about acids and bases in their previous lesson and were extracting pigments from various local flowers that were used to test for presence of acids or bases in laboratory reagents and local fruits like oranges, grapes and limes. She explained:

We made use of indicators...the ones available in the lab... we are now trying to extract indicators from flowers and we will use it to test for acids and bases... we will test them in those things (pointing at the fruits)... (Lesson observation 19/3/02)

Angy’s idea that the use of laboratory indicators and those extracted from flowers by her students could extend students’ understanding about the concept of acid and bases exemplifies her understanding of both content and students learning. Her wholistic understanding of this topic, knowledge of students learning and knowledge of context were exemplified in her extension of the science of acids and bases to incorporate local flowers and fruits which the students were already familiar with in their environment.

Angy’s PCK was also reflected in her ability to manage student inquiry. She demonstrated this ability during her second lesson, which started with a teacher-led demonstration. She demonstrated the test for starch using iodine solution before the
class and designed activities in which her students were also involved in testing for starch in local food items like yam flour, corn, cassava flour, and dried fish and so on. The student groups had described the colour change observed during the activity in several ways. For instance, while some groups described it as blue, black, or dark brown others described as greenish black, bluish or blue-black. The colour change was almost becoming a controversy among them and they asked her to describe the colour which indicated that starch was present in the items. Rather than give a direct response she simply told them to describe it as they saw it.

She was probably aware that the students were going to obtain a consistent blue-black colour change when starch was present in each of the items and wanted them to improve their knowledge about identifying colours changes in science. Her response prompted some interactions among the students as they compared their results with one and another and later reached a consensus among themselves and came up with the correct description of the colour change. (Lesson Observation 8/4/02).

Angy recapitulated most of the lessons observed by synthesising ideas generated from class discussions in a concise, logical and easy-to-understand form without referring to the outlines in her lesson plans. Angy was usually swift to detect students' misconceptions during lessons. She led the class to correct such misconceptions or provided the corrections when necessary to do so and she was never observed to evade students' questions. Her illustrations and analogies were consistent with the current understandings about Integrated Science content.

The ability to deal appropriately with students' misconceptions was demonstrated during her third lesson. The topic was "Rusting of iron." A student had said during a class discussion "When the iron had stayed long in my father's yard they become old and... rusty." Rather than give a spontaneous oral response which she probably thought many of her students might not easily understand, she responded by giving out samples of both rusted and un-rusted iron nails, and pieces of iron rods, to students to observe. She was concerned about the students grasping the concept. She tactically directed the discussions to focus on why iron rusts. Then she explained:

They (iron rods) don't become rusty because they become old... They don't grow old ...do they? They have been left ...exposed to conditions
that make them rusty... when we go through those experiments (pointing to the side benches), you will find out certain things... conditions that make iron to rust...I will only say that if iron is well protected it will not rust. (Lesson observation 22/4/02)

She led her students (working in groups of six or seven) through class activities designed to identify conditions necessary for rusting to occur.

The way she responded to the misconception in the lesson was tactical and demonstrated an integrated understanding about content, pedagogical skills and how students learn in science. Angy's involvement of her students in class activities seems to be consistent with her belief that “students learn science better by doing activities” (Interview with Angy, 8/3/02). Even though she encouraged student-student interactions which apparently facilitated their learning, the lessons were largely teacher directed, teacher-centred because she led most of the class demonstrations and discussions. Her students were to strictly follow procedures designed to achieve specific lesson objectives. She had explained during an interview: “They would not know exactly what to do...they should follow instructions regarding skills and participate fully...they should be able to demonstrate the skills required for the lesson” (Survey Questionnaire, 2.13).

Another attribute of Angy’s PCK is her ability to design practical exercises to reinforce the concepts already taught in other lessons or to improve students’ learning through repetitive practice of discrete skills in keeping with her beliefs that “science should emphasise learning of skills” (Interview with Angy, 8/3/02). She designed about nine practical exercises with specific procedures that the student groups carried out on a weekly rotational basis. She adopted this practice as a way of managing the very limited laboratory resources in her school. The practical lessons and the 'theory' lessons were carefully matched to each other even though many of the practical activities and the matching theory lessons were taught weeks apart. She seemed to be specific about what the practical lessons were designed to achieve. For example, a student group investigated the concept of solubility using both cold and hot water as solvents, table and other salts as solutes, and plotted graphs of solubility against temperature. Although Angy had earlier explained those terminologies in a lesson on solubility, the practical lessons reinforced the specific concepts; provided the opportunity to involve her
students in hands-on activities so that they can confirm or investigate ideas and learn practical skills in the process.

Her PCK was also reflected in the ability to make the students explore concepts from different angles. She was able to skilfully employ questioning to engage her students in class discussions leading them to explore all possibilities and reflect on their understanding. She moderated their discussions and occasionally pulled the class back to the main issue, at the same time demonstrating respect for their views. Angy would lead by asking follow-up questions like "Does anyone see another possibility?" or "Who would like to comment on Ade's idea?"

Most of the activities in her lesson challenged the students to construct understanding and engaged them in meaningful learning. She seemed to emphasise inquiry-based learning and encouraged depth rather than breath, moving rather slowly from one topic to the next. Angy's PCK appears to reflect an attribute of adequate pedagogical skills in her clear directions and procedures in most of her classes; her oral and written communications during her lessons were clear and effective. She was able to simplify and express science concepts and definitions in multiple ways as she was apparently trying to help her students understand concepts and also to model good communication skills.

The lesson on food storage exemplified her knowledge of student learning, context and content knowledge about food storage. She had set a main objective that at the end of the lesson students "should be able to appreciate the need for appropriate food storage and identify various methods of doing so." After her short preview of previous topic, Angy provided various local food items and asked students to observe and separate the bad ones from the good ones and give reasons for their decisions. She led a discussion on food storage in which she encouraged students to tell all they knew about food storage in their homes, used examples that her students were familiar with, and seemed to consider the previous knowledge that the students brought into the lesson as important. Students' misconceptions about food storage were also discussed.

Angy created a learning environment in which her students became curious and the zeal to learn more was apparent. She seemed to have integrated her knowledge of content with her pedagogical understanding (leading students in activities in order to facilitate
their learning) in the lesson. It was apparent too, that her understanding about the context of learning (local environment and students' background) and the way she believes students learn in science contributed to the overall student learning in that particular lesson. She also seemed to have blended her understanding of these knowledge domains in her ability to select a specific activity to develop the concept of food storage in the lesson.

Her understanding about student learning was further demonstrated when she expressed her belief that students should “learn science by doing activities” and that her students “learn best when they are kept busy doing class assignment or hands-on activities” (Interview with Angy, 8/3/02). She seemed to understand that giving information to students in the class or telling is not teaching. She alluded to this fact in her comment about how her students learn:

...Sometime they want to learn by receiving every information from the teacher...and when you asked them to study certain things on their own, they tend to get confused...probably this is because they don’t have reading materials...However as their teacher...I think that some of us know what to do...giving them information will not help much; we are to teach them... (Interview with Angy, 8/3/02)

Her comment about what she derives from the environment for her teaching further exemplifies her understanding of context:

But we have to be able to get some things too...sometimes we don’t really use only chemicals or reagents...What of insects, leaves, flowers...sometimes toads, lizards or fish? This environment contains a lot of these things. It’s difficult but I know how to get many of them ...I use my students sometimes and they are always happy... (Interview with Angy, 8/3/02).
Summary

Evidence arising from the analysis of the Survey Questionnaire, interviews and this case study corroborate each other regarding Angy's beliefs about the nature of science, effective science teaching and classroom teaching practices. Angy believes in the inquiry and dynamic nature of science. She also believes that science is a process for doing things, and a process of investigating and developing understanding about the natural world. Angy believes that science is taught in the school in order to produce future science-related professionals and scientifically literate individuals and that the science curriculum should emphasise both content knowledge and inquiry in science. While Angy believes that the Lagos State's Integrated Science curriculum is comprehensive, flexible enough to enable her apply various teaching methods and has achievable objectives, she does not believe that the document is current enough or relevant to students' needs.

Angy believes in a combination of teacher-centred and inquiry-oriented pedagogy. For effective science teaching she believes that both the teacher and the student should be involved in the teaching-learning process, that the teacher has to be able to explain and demonstrate the concept and skills involved, encourage student participation, possess the capability to improvise teaching materials where necessary or be able to get them from the environment. Angy believes that students learn science best by doing; when they are actively engaged in class activities under the supervision of the teacher, and when they feel free to interact during lessons. Angy views science as a dynamic process having to do with inquiry.

She believes that students should be assessed in various ways and as many times as possible as long as the teacher considers it appropriate and contributes to teaching and learning. She is of the opinion that students’ knowledge, skill and attitude should be assessed and that assessment should involve written examinations, class tests, quizzes, projects and laboratory practicals.

Angy's teacher-centred, and inquiry-oriented teaching philosophy is reflected in her teaching style which was characterised by a combination of teacher-centred and student activities involving teacher-led whole-class discussions, student engagement in class activities and meaningful learning.
Angy's goals for her students are to develop interest in science subjects, promote their confidence, and help them to become literate in science; because she believes that scientific literacy makes people live better lives. This philosophy was translated into action when she often said positive things about her students' responses in her lessons. For science teaching to be effective, she believes that the class must be manageable, and with enough materials so that students can learn science by doing activities. She believes in teaching and learning of skills in science. Angy believes that the teacher's role in the class is to try to explain concepts, ask and respond to questions, demonstrate necessary skills and guide the students to learn those skills through class activities, that students should be free to ask questions, listen to instructions and take part in class activities. She believes that her teaching is effective because she tries to teach science skills, particularly those mentioned in the scheme of work and her students' responses are encouraging.

Classroom Practice

Angy's designs of lessons reflected careful planning and lesson organisation based on prepared lesson notes with set objectives. The lesson notes incorporated tasks, roles and interactions fairly consistent with inquiry in science teaching and learning. She provided resources for her structured procedures of guided inquiry. Even though she initiated most of the interactions, student-initiated interactions were common. Students were encouraged to ask questions, take part in group activities, exchange ideas, and provide clues to questions or problems before she made clarifications.

Angy kept her students engaged either in class discussions or doing activities most of the time, spending more time going round her class to view group activities and listen to students' ideas. She uses questioning extensively and she would not readily release information. She seems slow in content coverage, prompting students to think through specific questioning and requiring them to explain their answers. Students' learning in her class appears quite significant. Even though she would introduce her lesson with a brief lecture, in most of her classes students seem adequately engaged with ideas and group activities relevant to the focus of her lesson.
Angy was able to vary her strategies making use of the lecture, whole-class discussions, and inquiry-oriented approaches at different times depending on her classroom situation. She seems quite confident, knowledgeable about science content; simplifying concepts in her own words, without reference to any text materials, drawing examples from students’ homes and school environment. Angy appears to take into account her students’ level of development, learning difficulties, and school constraints in planning and teaching her lessons.

Like the other teachers, Angy holds beliefs consistent with teacher-centredness in science teaching; she also espoused beliefs about students’ engagement in hands-on activities in science teaching and learning. Her teaching practices and styles are in keeping with her espoused beliefs and a combination of the lecture and teacher-led students’ activities were observed in her lessons.

Angy’s PCK was sufficiently developed to enable her to address students’ misconceptions, to design specific activities to reinforce the concepts taught in the class and enable students to learn isolated skills in science. Her PCK was reflected in her clear directions and procedures in most of her lessons. She was able to simplify science concepts and definitions in multiple ways, as she was trying to make her students understand and model good communication skills as well.

Even though these PCK attributes or components were not yet developed substantially or fully integrated to a level consistent with effective teaching and learning in science as outlined in chapter 2, she seemed to have adequately blended her knowledge of content, her pedagogical understanding (leading students in activities), her knowledge of context (local environment and students background) and her understanding of how students learn in science in a manner consistent with both her beliefs about teaching and learning in science and the context in which she worked. Furthermore, her classroom practices reflected a general PCK associated with class control and management and lesson note preparation.
CHAPTER 7: CASE STUDY 3

Introduction

This Chapter presents the result of the third case study, which involved Kaudry. Data were collected by interviews, lesson observation sessions, informal discussions and analysis of curriculum documents. The case study is presented in six major parts. Presented first is Kaudry's profile as a teacher followed by the context of science teaching in his school. The third part presents his pedagogical beliefs while the fourth part is the teacher's classroom teaching practices. Presented in the fifth part is the analysis of the teacher's practices in terms of pedagogical content knowledge (PCK) and the sixth part summarises the Chapter.

Teacher's Profile

Kaudry is a 33 year-old science teacher in a rural school in Lagos, Nigeria. He had been teaching science at the secondary level for 13 years, six of which were in his present school. He holds a National Certificate in Education, and a bachelor degree in science education. Being an acting head of department, he is highly respected among his colleagues and students. Apart from the responsibility to provide instruction in science that meet the needs of all his students, he had other job functions which include organising the weekly roster of teachers who conduct morning assemblies, coordinating terminal examinations for the junior secondary year two and three classes and supervising the school library. He is responsible directly to the Vice Principal of the school. He is the most senior of the three integrated science teachers in the school and his involvement in science teaching at the junior secondary level is 36 periods per week, six of which are assigned to three double-periods of practical classes. Kaudry's goal for his students is to help develop their knowledge in integrated science so that they can perform well both in their internal and external examinations. He stated:

...our major goal as their teacher is to teach them...and develop their knowledge in science so that they can do well in their examinations...I mean in their terminal and promotion exams...and of course their final...external JSS 3 examination. When they do well like that...that is when people appreciate our work... (Interview with Kaudry, 25/4/02).
He appears to be quite comfortable with his teaching styles describing what he does best as giving adequate explanation of concepts in class, clarification of issues in science and ensuring that students pay attention and take part in all class activities.

**Context of Science Teaching**

Kaudry's school is a rural school located close to the riverine area in the Lagos State of Nigeria. It is the only public school in the area. The majority of the people living in the suburb are illiterates and semi-literate individuals with a few literate civil servants, and businessmen and women living among them. The majority of the parents of the students are fishermen, traders and craftsmen. It is a coeducational school, with a population of about 3500 students.

Integrated Science is taught as a compulsory subject in all junior secondary classes. Each of the year groups has between three and four streams and there are three science teachers assigned to teach Integrated Science in junior secondary classes. The school has a separate laboratory for Integrated Science apart from those for Chemistry, Biology, Physics, and Agricultural Science. Integrated Science is based on the content and guidelines in the National Integrated Science Curriculum for Junior Secondary Schools (FME, 1980) and the Lagos State's Unified Scheme of Work for Integrated Science, (Lagos State Ministry of Education, 2001/2002) which itemises the science content to be covered weekly over the three school terms.

Kaudry followed the curriculum as laid out in the junior secondary science texts – the Nigerian Integrated Science Project, Books 1-3 (New Edition), (STAN, 1984). He also used the teacher's diary, lesson notes, teacher's handbook, continuous assessment record book (mark book) and teacher's weekly timetable. The documents are considered essential for teaching in the Lagos State's school system and are adequately supervised. Signatures of superior officers of the school and that of school inspectors were seen visible on some of the documents indicating that the use of such materials for science teaching is being supervised.

Displayed on the side benches in the Integrated Science laboratory were labelled bottles of reagents; acids, bases, salts, methylated spirit and other organic alcohols, and benzene. There were about 12 microscopes, all of which were said to be in good
working condition but appeared quite old and a number of hand lenses (about 20) stacked together in a side cupboard. There were models of the human skeleton, models of human body parts and organs, birds’ skeletal system, about eight water baths and a large aquarium, flasks of various sizes, funnels and about six plant pots displayed on the side benches. There were charts of various kinds ranging from the periodic table of the elements, energy flow system, to drawings of the human and other animal organs hung on the walls of the laboratory. There was an inner storeroom in the laboratory in which electrical apparatus like ammeters, voltmeters and a weighing balance; stop clocks and other delicate instruments were kept. Although Kaudry complained of occasional power failures, the laboratory was supplied with both electricity and water. It was apparent that most of the materials available in the laboratory would be insufficient for Kaudry’s classes of about 50 students. The classroom environment however, appeared conducive for learning with enough seats, good ventilation, enough space for teaching-learning activities and students appeared quite comfortable in most of the lessons observed.

Teacher’s Views

The Nature of Science

Kaudry believes that science is a way of studying and developing understanding about the natural world (Survey Questionnaire, 3.9). He also believes that science is a process of doing things and that the knowledge of science is always improving. Kaudry believes that people study science in order to have the capacity to solve problems and contribute to society. Explaining the nature of science, he stated:

Science is just doing...unlike other disciplines, it makes you learn and practice what you have learnt...you know, you observe things... and at times you collect data and you also analyse... and you know, after studying science... when you identify a problem you can then try to find a solution to the problem in a scientific way...(Interview with Kaudry, 25/4/02).

Kaudry indicated that scientific knowledge keeps improving and that the study of science helps people contribute to society. He reiterated:

...The nature of science can be viewed in a broad sense...you know that science is always dynamic; it is never stagnant or static...it keeps
improving...Again it makes those who study it somebody at the end of the day after a course of study in science...you know as the interviewer, 'am sorry to say...look at some of our important people in our society today...because they have gone through the study of science...and I too, 'am trying to make a career out of science...it makes you to be sound in knowledge...you will be able to contribute to the society and people will begin to look at you as a role model... (Interview with Kaudry, 25/4/02).

Kaudry wants his students to view science as a subject that will enable them to solve most of their problems in life, and he believes that science is taught in school in order to pass some basic knowledge from one generation to the next. He stated:

...I would like my students to view science as a subject that can make them solve most of their problems...You know the various problems that confront the human race...this is why we teach them science...You know that generations come and go...science is taught in schools in order to replace future leaders...by the time some leaders are phased out, they are replaced with new ones, so science is taught in the schools to prepare our future leaders...it makes us to be able to replace professional experts...so that some basic knowledge can be passed from one generation to the other... (Interview with Kaudry, 25/4/02)

Kaudry believes that the science curriculum should emphasise both content knowledge and inquiry in science. He believes that the Lagos State's Integrated Science curriculum is both comprehensive and relevant to students' needs. He however believes that the document is not current and has not been reviewed for many years (Survey Questionnaire 5.1, 5.2).

**Assertion 7.1**

Kaudry believes that science is a process of developing understanding about the natural world and that scientific knowledge is always improving.
Assertion 7.2
Kaudry believes that science is taught in order to produce science professionals, so that some people can become future leaders, the science curriculum should emphasise both content knowledge and inquiry in science.

Effective Science Teaching

Kaudry believes that science teaching and learning is most effective when the teacher takes control of the class, presents his/her lesson by giving adequate explanation and demonstration of the concepts, provides the necessary materials for the students to learn and allows the students to take part in the lesson. Kaudry's idea about students taking part in a lesson was found to mean that students should listen attentively and respond to questions. He espoused the beliefs that students' roles in an effective science lesson should include listening attentively in class, asking and answering questions and taking part in group and individual assignments (Survey question 2.13). Explaining the teacher's roles in an effective science classroom, he stated:

...One of them is demonstration... this is because the teacher teaches in the front of the class... or while moving around he has to demonstrate so that the students can understand the concept... not just passing the theoretical information alone... he has to demonstrate so that the students can learn by it and he should be able to take control of the class... and be able to carry them along. He has to explain too... he should be able to develop his points about the concept and be able to carry the students along all the time... at times you ask questions and you also respond to their questions and many other things like that...(Interview with Kaudry, 25/4/02).

He is of the view that students are supposed to answer questions, write down notes and observe the teacher's demonstrations. He explained:

... The students are supposed to give a feedback... their feedback should involve answering of questions... When you outline your points and give
it to them...they have to write them down in their notes, observe your demonstrations... and you try to keep them alive by asking them questions...you can even make them contribute part of the points you are giving them ...and you can ask them to give examples on the concept...(Interview with Kaudry, 25/4/02).

Kaudry appears quite comfortable with his teaching strategies describing what he does best in his lessons as explaining, demonstrating and 'sometimes' allowing the students to express their views. He stated:

...when I am teaching I make sure that I adequately explain the concept, ...I also demonstrate and sometime I give the students real objects to work with...I even sometimes allow them to express themselves ...you know... we can also learn from them...those are the things I do in my class...(Interview with Kaudry, 25/4/02).

Student Learning

For science teaching to be effective Kaudry believes that students should listen and observe the teacher’s demonstration, write down the points being given by the teacher, and answer questions in the class. He explained:

...For science teaching to be effective...as the teacher outlines the points and gives the information to them... and as he demonstrates...they have to listen attentively, write down the points in their notes...observe the teacher’s demonstration ...and try to provide feedback by asking questions on the areas they did not understand...(Interview with Kaudry, 25/4/02).

Kaudry’s beliefs that his students learn best when he is able to explain concepts, back-up the explanation with illustrations, and tries to get them involved in the teaching-learning process, as explained in the interview, appear to corroborate that which he expressed in the survey questionnaire (Survey Questionnaire, 2.13). Describing how his students prefer to learn, he stated:

...They prefer to learn when you adequately explain the concepts...especially those difficult concepts...you bring it to their familiar level...and you try to put life into whatever you are
teaching...you let them see what you are doing...you are not just passing the bulk of the information, you back it up with illustrations...and you let them do some practicals...That is how they learn effectively...and we try to see that they learn by those methods...(Interview with Kaudry, 25/4/02).

Student Assessment

Kaudry believes that students are assessed in the school in order to know their academic achievement, promote them to the next class, and prepare them for external examinations and to give their parents feedback. He explained:

...You know that they are here for a purpose or to achieve some goals...we assess them to know their achievement...whether they are improving or not... in order to promote them ...may be to the next class or prepare them for external examinations...we also assess them in order to give feedback to their parents...You know they have been sent to school by their parents...so, at the end of the day they are given report cards or result sheets to show their parents how well they have done...(Interview with Kaudry, 25/4/02).

Kaudry assesses his students mainly through periodic examinations, quizzes, and terminal examinations and occasionally assesses their attitudes. Describing how he assesses his students and the aspects of learning involved, he explained:

...We do examinations...they have just concluded some examination now; we give them periodic examinations and terminal exams. We give them periodic tests and quizzes also and...sometimes we give them group projects and make sure the members of each group contribute... they have to submit their group work for grading and we try to look for their participation.... Sometimes I also assess their attitude...I try to see the way they go about whatever is given to them to do in the classroom...I watch their reactions, their perseverance level and things like that... how they make use of their senses...we assess all those...(Interview with Kaudry, 25/4/02)
Assertion 7.3
Kaudry believes that for science teaching to be effective the teacher must take control of the class, have good knowledge of the subject matter, be able to explain, illustrate and demonstrate the concept being taught, and should allow students to be part of the teaching-learning process.

Assertion 7.4
Kaudry believes that students should listen in the classroom, observe the teacher's demonstrations, ask/answer questions and take down notes.

Assertion 7.5
Kaudry believes that students are assessed in order to know their academic achievement, promote them to the next class, and to give feedback to the parents, and he assesses his students by given periodic tests, quizzes, projects and terminal examinations.

Classroom Practice

Introduction

Five of Kaudry's lessons were observed during weeks three to 10 of the third term which began on the 15th of April 2002, in the 2001/2002 academic year. Each lesson was preceded with a pre-observation discussion usually focused on the teacher's preparations for the lesson, lesson objectives and expectations from the lesson. After each observation, a post observation discussion also took place during which the teacher's impressions about the lesson, clarifications regarding methods employed and plans for the next lesson were sought. Kaudry had between 47 and 52 students in each of the classes observed.

Pedagogy
Planning and organisation

Kaudry's lessons reflected careful planning and lesson organisation based on prepared lesson plans (also sometimes referred to as lesson notes), which specify what the students should be able to do, learn or understand at the end of lessons, outlines of teaching procedures and set of activities for each lesson. The lesson notes were prepared using the State's Scheme of Work for each school term as a guide and curriculum content derived from the recommended textbook (STAN, 1984). The lesson note seemed adequately supervised by the school system as school inspectors' signatures and that of the Vice-Principal were found on many of them.

The way in which the lesson contents were structured seemed hierarchical, from simple to complex, and the learning objectives appeared to be significant and worthwhile for the level of the students. Kaudry made use of the recommended textbook, his lesson notes, charts and diagrams in most of his 'theory' lessons. Unlike other lessons, there was no lesson plan prepared for the practical lesson (Lesson three); however, the practical procedure (derived from the textbook) was written on the board for the students to follow. Unlike other lessons observed, students were made to carry out some guided hands-on activities in a somewhat prescribed fashion during the practical lesson.

Interactions

Kaudry initiated the majority of the interactions. Student-student interactions were not common except when they had to work in groups during the practical class. He usually opened his lessons by asking two or three questions about the concepts discussed during the previous lesson and each time three or four students would raise their hands to answer the questions. He rarely made use of questioning in his teaching, and when he did, most of the information elicited did not go beyond the recall, short-answer responses as the questions required students to demonstrate they were paying attention. Teacher-student interaction appeared to be influenced by a cultural environment in which the teacher is seen as the 'master' and 'authority' that can hand down discipline on any one if found wanting. The class was quiet in most of the lessons, which suggests that the students were either unwilling to interact among themselves, did not feel free to
do so, or were waiting for the teacher's encouragement to do so. Most of the lessons were relatively orderly and quiet but not entirely passive because some students were copying notes from the board, and reflected an environment in which traditional teaching and learning activities were taking place.

**Teaching style**

Kaudry frequently made use of the transmission-oriented, and teacher-directed teaching strategies employing detailed explanation and illustration of concepts coupled with teacher-demonstration and occasional questioning. Most of the lessons that were observed involved the traditional, teacher-directed, whole-class teaching. Interactions were mainly between teacher and students; like inviting students to answer questions, asking them to state definition of concepts or principles and asking them to give examples. Interactions between the students were minimal. While most of the lessons were teacher dominated, the students were not entirely passive. They were involved in answering questions, trying to write notes from the board, listening to the teacher and other students who answered the teacher's questions. The majority of the questions, however, appeared to be low order, recall questions requiring knowledge of facts with only a few requiring students' explanation of their ideas. The emphasis in most cases was to encourage the students to get the right answer.

Students' responses and ideas expressed in most of the lessons seemed to have been recalled either from their notes or from the textbook. For instance, Kaudry's first lesson observed was with a JSS 2 class and the topic was 'measurement'. He opened the lesson by asking two questions based on what he taught in the previous lesson. "Who can define mass?" and "Who can give us the definition of weight?" he asked. Two or three students responded. Some of them seemed either trying to recite earlier definitions given to them or read from their notes. Kaudry did not react to the responses but went on to write the day's topic on the board and told the class they were going to discuss measurements of density and force starting with density. He continued:

... The density of a substance is the mass of the substance per unit volume...we sometimes need to compare densities of many substances. You know the density of water is...somehow fixed, and it is taken as a standard to which all others are compared. Who can give us the density of water? (No response)...when we compare other densities with that of
water, ...like that we have what is called the relative density (wrote the definition on the board)...density varies from substance to substance...You know that for the same type of things the density is always the same.... and you know that for things that are different, they cannot have the same density...I want you to take note... that things that are the same have the same density... The hydrometer is the instrument used to measure the density of liquids... (Lesson Observation, 15/5/02).

Kaudry showed a hydrometer to the class by raising it up so that everyone could have a view of it, drew it on the board fully labelled and asked the students to copy the diagram into their notes. He spent the next 10 minutes writing notes about the procedure for measuring density of liquids on the board for students to copy.

He went on to illustrate how force can be measured using a spring balance. He held a spring balance to which a small pan is attached and demonstrated the processes of extension and release by adding weights to the pan and removing weights from it. He further explained:

... you find that if an object is suspended from a spring... the spring becomes extended as I have just shown you...'am sure you have seen it before don't you (a chorus response “yes”)...the weight of the substance makes the spring to extend, and it returns to the original position when the weight is removed...The more weights you add to the pan the more extended the spring becomes...and we then say that the extension...that is the increase in length of the spring is proportional to the amount of weight added...(Lesson Observation, 15/5/02)

Kaudry was in the middle of illustrating how the simple spring balance could be calibrated to measure force, while the students were busy responding to questions and at the same time drawing the diagram of the spring balance into their notes when the bell signalling the change of lesson interrupted the class.

Kaudry’s methodology during the second lesson on ‘the simple machines’ did not deviate significantly from that of the first. He had written the topic on the board after a brief opening based on his previous lesson and he seemed satisfied with the chorus answers that followed the two questions he asked. He defined the concept of machine
and wrote it on the board, informed the class that they were going to learn about two major groups of machines – the lever and the inclined plane, listed on the board the different kinds of machine like the lever, inclined plane, screw, and the wedge as examples of machines. He explained:

...when we say machines, some of them are very simple and ... that is why we call them simple machines. You find out that anything or any device that enable us to do our work in an easier manner...that makes it easier for us to do our work... is called a machine...You find out that the purpose of using the machine is to be able to do our work more conveniently...You may not realise that some of the things you use in the house...I mean... in your homes are actually machines...I mean things like...knives, hoes, axes or even the wheelbarrow...(Lesson Observation, 20/5/02)

Kaudry frequently listed points on the blackboard during the lessons. He gave detailed explanation of each term and concept with appropriate examples drawn from the environment. He frequently asked questions like “Who has seen...?” “Who can give example of...?” “Who can tell us...?” and occasionally, “Who can explain...?” Each of the machines listed on the board was discussed in turn with annotated diagrams of typical examples in the homes to demonstrate how they can be used to do work. The students were still busy copying from the board when the bell rang for the short break. Kaudry had to give the instruction that the class should wait behind to complete their notes.

Kaudry’s practical lesson (Lesson 3) seemed to deviate a little from the other lessons observed. The practical lesson was more student-oriented as it provided the opportunity for students to carry out some guided practical activities in the laboratory in a somewhat prescribed fashion. Ray boxes, plane mirrors, protractors, and worksheets were provided for the practical activities designed to determine the angles of incidence and reflection of a ray of light falling on a plane mirror. Unlike other lessons, there was no lesson plan prepared for the practical lesson. The practical procedure (derived from the textbook) was written on the board for the students to follow, and the students worked in groups of four or five. Organising the practical lesson was also more involving for Kaudry as he was observed collecting materials from different sources in the laboratory and ensuring that each group of students had materials to use for their practical
activities. When asked if there were enough material for teaching practicals in the school, Kaudry explained:

...we have problems of teaching materials in this school; especially science equipments...I think the situation is the same with all these schools in this LED, at least...we meet ourselves sometimes at the LED office...I mean we science teachers and we discuss this problem. They are not just enough ...you see...these ones (pointing to the ray boxes), we borrow them from the physics lab...for a long time now, I mean since about two years now nothing has been provided for this lab...you can see that these things here...most of them are very old. We are more in numbers here so...they should provide more things here because I believe that JSS classes are equally important... (Post-observation discussion, 20/5/02).

The relationship between the practical and theory was not apparent to the Researcher because the last lesson with this particular group was on simple machines. Furthermore, the students were made to follow a prescribed practical procedure during the practical exercise in which manipulative skills were practised.

Kaudry’s fourth lesson was also dominated by teacher-talk. Appropriate knowledge of science content was reflected in the way he organised and presented the information in a simplified lecture fashion. He was fluent, confident and coherent releasing the bits and pieces of information without referring to the textbook or the lesson note on his table. While these teaching activities demonstrated appropriate content knowledge, pacing in the lessons seems to reflect inappropriate pedagogical style. Pacing and coverage of content were obviously not suitable for the students. There were no opportunities for lesson closure and the rush to cover large areas of content without regard to student understanding created an atmosphere of boredom particularly in lessons two and four observed. He had written the topic for lesson four: ‘Elements, Compounds and Mixture’ on the board after opening the lesson in his usual manner by asking one or two questions and did not react to students’ responses. He then hung the chart of the periodic table of elements at the right corner of the chalkboard. After he had asked the class to pay attention and to focus on the chart, he drew their attention to the arrangement of elements in increasing atomic number. He gave the definition of
element, compound and mixture and wrote them on the board, faced the class and asked the students again to listen and continued:

...elements cannot be broken down into anything else...they cannot be broken down into simpler form by both physical and chemical processes...The symbol of each element represents the atom of that element and...it is distinct...quite different from the atom of other elements. You should know that elements are pure substances...Oxygen for instance consists of only one element and nothing else...i.e. only one kind of atom...the two atoms that make up oxygen gas are the same...The sodium chloride and water are not elements... (Wrote their chemical formulas on the board)... they are compounds ...because they can be broken down into simpler forms. The salt sodium chloride consists of sodium metal and chlorine gas... while water is made up of hydrogen and oxygen... (Lesson Observation, 12/6/02).

Kaudry moved quickly to explain the concept of mixtures giving various examples, how the mixture can be separated by physical means and so on. The class was quiet, some of the students focused on his writings on the board trying to copy the information into their notes while others who obvious could not cope with the pace were either gazing at the periodic table hung on the board or listening and watching him. He had listed some substances: air, candle, table salt and water, on the board and asked the students to classify them into mixtures and compounds and give their reasons. His first mentioning of ‘air’ was greeted with mixed responses from the students, some of them were observed trying to look through his earlier examples before responding and the bell signalled the end of lesson.

The pattern of lesson delivery in the lessons, so far reported, indicates that Kaudry is very much locked into the traditional teaching method in which he acts as the sole information-giver to a relatively passive class of students. He appears to emphasise the learning of answers more than the exploration of questions, and memory at the expense of critical thought. A review of the lessons one through to lesson five observed also reveals that Kaudry did not appear to implicitly encourage students to work together (except for the practical lesson), to share ideas and information with each other or to use any instrument to extend their understanding or intellectual capabilities.
### Assertion 7.6
Kaudry's teaching style is characterised by teacher-dominated, didactic activities involving teacher-talk, explaining, demonstrating, giving notes to students, and emphasising knowledge of facts in science.

### Assertion 7.7
The majority of Kaudry lessons were driven by teacher-talk at a fast pace which encouraged superficial coverage of large amount of content and he rarely made use of questioning.

### Assertion 7.8
Kaudry's practical lesson was based on a prescribed practical procedure, which the students followed explicitly.

The last lesson observed which was on growth and development was also driven by teacher-talk and depended heavily on facts derived from the textbook, creating the idea that there is a fixed world of knowledge that the students were required to know (Hanley, 2001). Kaudry's objective for the lesson was: "Students should be able to explain the terms: growth, development and maturity; mention some factors that affect growth and development; and identify the roles of such factors in the process of growth." Kaudry introduced the lesson by asking two questions on the previous lesson with the class, which was on excretory organs, and three students responded and he reviewed the last lesson in about two minutes. After he had repeatedly mentioned the day's topic and what it was all about, he wrote it on the chalkboard and continued again in a lecture fashion.
...You, no doubt, have increased in height, weight...over the years...and some of you probably have younger sisters and brothers who are still babies...You see, you were like those babies before you grow up to what you are now... Your becoming taller, fatter or...heavier...are signs of growth that have taking place in you... Have you noticed some changes in you since the past two or three years? (Two students responded). There are some things that you were not able to do as babies but you are able to do them now...these changes are not because you are growing only, you are also developing; they are signs of development...you see, growth and development occur in every aspect of our life...but we will limit our selves to what happens to our body only... (Lesson Observation, 19/6/02).

Kaudry explained the terms development and maturity, using the organ of reproduction as an example. He listed the factors that are necessary for growth on the chalkboard and, one after the other, outlined their effects starting with that of heredity. The class was unusually quiet; the students appeared focused probably because of the somewhat familiar examples the teacher was giving or listing on the board, and students' interaction was minimal. Providing the whole information, which he had divided into parts, he explained:

...I am aware of this fact that many of you resemble your parents; some of the boys here very much look like their fathers...You are familiar with the saying "like father like son" or "like mother like daughter". There are minute particles that are present in cells of living things...these particles are called genes...these genes are the units on inheritance...You resemble your parents because you have their genes transferred to you...they are responsible for most of the resemblance or similarities between people who are blood relatives. You see...the genes transfer certain features and characteristics from the parents to their offspring...therefore their offspring resembles them...or looks like them...do you understand? (No response)...the transfer is what we call heredity... (Lesson Observation, 19/6/02).
Kaudry had already summarised the main points on the factors necessary for growth in his lesson note. He copied these on the chalkboard for students to copy and had just written a take-home assignment on “the effects of diseases, exercise and rest on growth” on the chalkboard when the lesson came to an end.

Although the information given to the students in the lesson just reported was accurate and was given without reference to any text materials (reflecting accurate knowledge of content), the presentation was consistent with the traditional teacher-dominated lecture style in which the teacher seeks to transfer his/her thoughts and meanings to the passive students.

Assertion 7.9
Kaudry holds pedagogical beliefs consistent with a knowledge transmission teaching philosophy and such beliefs are reflected significantly in his classroom practices.

Assertion 7.10
Kaudry believes that the science curriculum should emphasise both the content knowledge and inquiry in science; however, this was not reflected in his science teaching and classroom practices.

Assertion 7.11
Kaudry attempts to rush and cover as large areas of content as possible within the time frame without involving the students in meaningful learning activities in most of the lessons observed.

Teacher’s reflection on practice

Kaudry appeared to be contented with the way most of the lesson went, given the constraints posed by school factors including large classes and insufficient science teaching resources. He believes that while the government is making efforts to provide the necessary resources for science teaching, the Parents-Teachers Association (PTA)
should also play a part in providing facilities for the school. When asked about how much he thinks that the students are achieving in their study and how he thinks the students prefer to learn, he explained:

I believe they have been doing well...except that...I think the standard has started to fall...For example we have been having more than 65% pass in their final examinations...the last year result which I still have in the office there was about 68% pass rate...unlike some years back...three or four years back...we used to have above 85%...and this is giving us some concern... Again I can say that many of them want you to make everything simple for them...they want you to give notes on everything you are teaching and to explain everything to them, you explain those abstract concepts...you bring it to their familiar level...you let them see what you are doing and the reason for doing it...when you give the information to them you try to back it up with illustration...and when they do practicals you let them use their hands, that is how I believe they learn effectively...I think that is how many of them prefer to learn science...and we try our best to see that they learn by those methods (Interview with Kaudry, 25/4/02).

Kaudry believes that the students have a poor attitude towards science. He complained of lack of seriousness on the part of the students and lack of concerns about the issue of poor attitude by the parents. He believes that he and his colleagues have tried their best over the years to encourage the students to develop interest in science subjects but nothing seemed to have changed. He explained:

...I know that we lack facilities...but most of these students are not serious...they don’t want to learn. We have tried our best to encourage them to have interest in their study... but many of them don’t really want to learn...honestly they are not changing their attitude towards science subjects...and we have continued to force them to do it...and their parents...probably because of the location here or this environment...they are not helping us at all, they expect the teacher to do everything...whereas they are the ones who are not encouraging their
children to learn...many of these children you see... are even running from school...Interview with Kaudry, 25/4/02).

Even though problems of noise were not observed in the school, those factors mentioned by Kaudry might be distracting the students’ attention. The inability to acquire the necessary textbook for learning may also discourage students from learning. This Researcher is of the view, however, that Kaudry was not only teaching the way he was taught, he also expected the students to learn the way he did. This view is supported by his reference to his time when he explained: “during our time there was discipline... and we were serious with our studies...” (Post Observation Discussion, 12/6/02).

Kaudry’s knowledge transmission pedagogy does not have the potential to develop students’ interest in science learning.

Assertion 7.12
Kaudry’s teaching style is a probable contributing factor towards the students’ poor attitude towards science.

Kaudry believes that the school’s location has contributed to the problem facing the school. He believes that some establishments like the new Local Government Secretariat and an international market with its accompanying restaurants have been brought too close to the school and are distracting the attention of the students who are predominantly rural dwellers. He explained:

...I see this school location as becoming a problem...This school have been here for a long time...now look towards the south...that is the Lagoon, and all these new building springing up towards the north and look at the Local Government Secretariat to the eastern part and now...look at the Alaba International market...you see all these put together interfere very much with our work...I mean they don’t make this environment conducive for the school to achieve effective science teaching. Another one is that... you see...because of this market restaurants are springing up around the whole place...I believe they attract our students too much ...this is too much exposure for this rural setting...they want to be out of school..., can you believe that some of
them want to go and have a nice time and... sometime they come late to school... (Interview with Kaudry, 25/4/02).

When asked if he observed any learning problems among the students apart from lack of seriousness and the distractions he already mentioned, he explained:

... the most important thing is this lack of seriousness... and maybe... many of them have become lazy... and maybe because they don't usually have the recommended textbook... When you give them homework,... they won't do it at home... and you find out that they copy each other.... Even when you explain the whole thing... they are just looking at you. At least during our time there was discipline... and we were very serious with our study... when the teacher explained things in the class, we go back and study... we study those things again and... who are you not to do your homework...? (Post Observation Discussion, 12/6/02)

**Assertion 7.14**

Kaudry's classroom practices appear to be more grounded in his beliefs about effective science teaching and about students' learning rather than on the constraints posed by school factors like large classes, insufficient facilities and an unconducive teaching environment or lack of support from parents.

Among other factors identified by Kaudry as limiting his science teaching effectiveness are lack of adequate encouragement by government and the society, irregular payment of science teachers' allowance, non-provision of in-service training, and insufficient number of teaching staff. When asked how he thinks the problem can be solved, he explained:

... yes quite a number of things can be done... this our society tend to look down on teachers generally... science teachers should be encouraged, we should not be looked down upon... because we do a lot to keep the society going. Another thing is that in-service training has to be provided and urgently too... especially in this school with high population of
students...and I know that we provide better education than the private schools. Government should employ qualified teachers... many of them are outside there looking for job and they are not getting it...I would like to say too...that the result of research like this can be made available...so that we can apply the findings to improve our science teaching...(Interview with Kaudry, 25/4/02).

Kaudry's concerns seem to confirm his views that he is doing the best he could to bring about effective science teaching and learning in the school. He probably views his knowledge transmission pedagogy as ideal for students learning in science.

**Overview of Teacher's Practices in Terms of Pedagogical Content Knowledge (PCK)**

The model of PCK described by Cochran, DeRuiter, and King (1993) considers teacher's subject matter knowledge, pedagogical knowledge, knowledge of students' abilities and learning strategies, and knowledge of the social and physical environment in which students are being asked to learn. Veal (1998) refers to these teacher knowledge components as PCK attributes. Kaudry's teaching practices are analysed in this section in relation to these components or attributes of PCK.

**Lesson Preparation and Organisation**

Kaudry's PCK in relation to lesson planning and organisation reflected various components or attributes that have developed to varying degrees. For example, he was able to design lesson plans, develop activities for the various Integrated Science lessons he taught. He specified what the students should be able to do, learn or understand at the end of each lesson, outlined the teaching procedures and sets of activities for achieving his lesson objectives. Each lesson plan also incorporated a set of assessment produces most of which were in the form of take-home assignments.

The way in which he structured the lesson content seemed hierarchical, from simple to complex and there were no content errors visible to this Researcher. The way he represented them (contents) in the lesson notes in terms of how it might be effectively taught and assessed
portrayed an understanding of content, pedagogy and how students should learn from a transmission model perspective.

Kaudry was specific about what he wanted his students to learn in each lesson and in the selections of activities to achieve his lesson goal. For instance the set objectives for his lesson on Growth and Development included: "Students should be able to explain the terms: growth, development and maturity; mention some factors that affect growth; identify the roles of such factors in the process of growth." (Lesson Note, 19/6/02). The organisation and representation of his lesson contents appeared significant and worthwhile for the level of his students.

Teaching Behaviour

Kaudry's PCK reflected various components or attributes that are derived from the traditional teacher-centred, knowledge transmission perspective. His classroom practices also reflected a general PCK associated with classroom management, control and discipline. Furthermore, Kaudry's PCK appears to have been influenced by his beliefs and his acceptance of a model of teaching with which he was taught. He alluded to this when he said:

.... Even when you explain the whole thing...they are just looking at you. At least during our time there was discipline...and we were very serious with our study...when the teacher explained things in the class, we go back and study ...we study those things again and ...who are you not to do your homework...? (Post Observation Discussion, 12/6/02)

An attribute of his PCK is a pedagogical style that reflected a tacit understanding that science can be best taught "in a quiet class" (Survey Questionnaire, Section 3.1) in which students are in total subjection to the teacher's authority. He had reiterated:

For science teaching to be effective, the teacher must take control of the class (Interview with Kaudry, 25/4/02)

He appeared to have taken a rather authoritarian control of the lessons observed. Such a level of class control does not reflect an understanding of the constructivist perspective of how students
learn in science. His transmission teaching philosophy seems to view understanding as coming from listening and receiving explanation directly in a highly controlled environment rather than as a result of active engagement in learning activities in which meaning is intimately connected with experience.

This attribute was demonstrated in the majority of his lessons observed. For example, he had opened a lesson on Measurements (Lesson one) by asking two questions based on his previous lesson. “Who can define mass? Who can give us the definition of weight?” Three students responded by trying to recite earlier definitions given to them or read from their notes. Kaudry did not react to the responses but went on to present the lesson by providing detailed explanation of the concept of measurement and summarising the main points on the chalkboard. He explained:

...The density of a substance is the mass of the substance per unit volume...we sometimes need to compare densities of many substances. You know the density of water is... somehow fixed, and it is taken as a standard to which all others are compared... Who can give us the density of water? (No response)... when we compare other densities with that of water, ...like that we have what is called relative density... (Lesson Observation, 15/5/02)

Kaudry employed a predominantly teacher-directed lecture method driven mainly by teacher-talk. His PCK also appears to be underpinned by his beliefs about students' role during the lesson in which he says, “students are to listen, write down notes and may sometimes be allowed to ask questions” (Interview, with Kaudry, 25/4/02; Survey Questionnaire, 2.13).

This attribute was further demonstrated during the fourth lesson observed. He had introduced the lesson in his usual style by asking two questions that three or four students responded to. He did not react to the responses. After he had hung the periodic table of elements on the corner of the chalkboard, he repeatedly asked the class to pay attention so as to have a quiet class in keeping with his beliefs as he provided explanations for the arrangement of elements in increasing atomic number. He continued in his monologue:

... Elements cannot be broken down into simple forms by both physical and a chemical process...the symbol of each element
represents the atom of that element and...it is distinct...quite different from the atom of other elements (Lesson Observation, 12/6/02)

The monologue was oriented towards providing students with a detailed representation and explanation of the lesson content. He seems to believe that students learn by being given all the information about what they need to know, that 'telling simply translates to teaching.' Kaudry rarely allowed students to ask questions and did not react to most of the students' responses. In keeping with his beliefs that students should learn by listening to the teacher's explanations, copy notes and answer questions (Survey Questionnaire, 2.13), he did not create an environment of good rapport in which students feel free to ask questions, neither did he make use of questioning substantially during his lessons. The few questions he asked were typically low-level recall requiring short factual responses. He did ask few questions like "Who has seen...?" "Who can give example of...?" "Who can tell us...?" and occasionally, "Who can explain...?"

Although Kaudry's pedagogy seems to be driven by his beliefs in knowledge transmission and is dominated by teacher-talk, his teaching reflected a PCK attribute of an appropriate knowledge of science content. His lesson organisation seemed coherent, and he represented the lesson content in multiple ways and in a simplified lecture fashion for students understanding. He gave detailed explanation of each term and concept with appropriate examples drawn from the environment. He also tried to relate the concept being taught to the students' lives. These attributes were demonstrated during his lessons two and four. Lesson two was on simple machines. He had listed on the chalkboard examples of simple machines like the lever, inclined plane, screw and the wedge. He explained:

...anything or any device that enables us to do our work in an easier manner...that makes it easier to do our work is called a machine. The purpose of a machine is to enable us to do our work more conveniently. You may not realise that some of the things you use in the house... I mean ...your homes are actually machines... I mean things like... knives, hoes, axes or even the wheel barrow." (Lesson observation 20/5/02)

Each of the machines listed on the board was discussed in turn with annotated diagrams of typical examples in the homes to demonstrate how they can be used to do work.
It was apparent that Kaudry was trying to represent or translate the concept of simple machines in ways that the students could understand. Drawing his examples from the student’s home environment and background exemplifies not only an appropriate knowledge of content but also an understanding of context. The way Kaudry tried to represent the concept of elements and compound is a simplified form for student understanding during his fourth lesson also exemplified his appropriate knowledge of content. He had explained during the lesson:

You should know that elements are pure substances... Oxygen for instance consists of only one element and nothing else... i.e. only one kind of atom... The two atoms that make up oxygen gas are the same (pointing to the formula of oxygen on a chart) ... The sodium chloride and water are not elements (wrote their formulas on the board... they are compounds because they can be broken down into simpler forms... (Lesson Observation, 12/6/02)

Kaudry was fluent, confident and coherent, releasing bits and pieces of information without referring to the textbook or the lesson note on his table. He tried to simplify and repeatedly stated scientific definitions and explanations in several ways for his students to understand. The majority of examples he gave during the lessons, analogies outlined and relationships drawn among topics reflected an accurate understanding about science content. For example, his ability to illustrate the concept of simple machines with simple home tools e.g. hoes, knives, axes (Lesson two) that may exist in his students’ homes exemplifies his ability to integrate his knowledge of science content, his knowledge of students and their home environment into PCK.

While his PCK reflected appropriate content knowledge, pacing in the lessons seems to reflect inappropriate understanding of the constructivist perspective of how students learn in science. Pacing and content coverage were too rapid preventing students from developing an understanding of the concepts.

Kaudry’s practical lesson (lesson three) was apparently designed to provide opportunity for students to carry out some guided activities in a somewhat prescribed fashion in order to reinforce the concept of light rays and reflections of light he had taught in previous lessons. He provided materials like ray boxes, plane mirrors, protractors and work sheet for students to
work with. He wrote the practical procedure on the board for students to follow and students worked in groups of four or five. He supervised and assisted student groups in setting-up the experiments. Although Kaudry explained the procedure to follow and ensured that every group had materials to work with, he did not explain why they were doing it or elicited any explanation from students. Student participation was restricted to working in groups, setting-up apparatus, watching him and listening to his oral directives. The practical lesson also appeared to be oriented towards providing opportunities for confirming or reinforcing the concepts learnt in other lessons and learning of isolated skills in science.

Kaudry’s belief in knowledge transmission pedagogy seems to have a profound effect on his pedagogy. Because of his beliefs in knowledge transmission, he made few efforts to elicit students’ representations and was unaware of how students were making sense of what they were to learn. He did not react to most of the students’ responses and maintained a distance from them. By maintaining a distance from his students and relying on transmission of facts he was not conscious of his failure to anticipate probable misconceptions and to address them during the lessons. In addition, he did not encourage student interaction to facilitate their learning because he believed that he needed to have control over coverage of content to ensure efficient learning and maintain high standards. His beliefs that students learn by being given all the information about what they need to know; that ‘telling simply translates into teaching’ was demonstrated in his classroom practices.

Simply providing the information does not necessarily result in learning (NRC, 1996, Hassard, 2000). Students need to be required to explore and re-visit concepts in different ways to personally and meaningfully make sense of them. Good learning is a coordinative process, which requires grappling with concepts and ideas through looking at them from different angles and through “thinking out loud” (Loughran, 1996)

From the perspective of the roles he played as a traditional teacher, Kaudry’s PCK reflected a sound knowledge of content and an understanding of context. His pedagogy however did not reflect an understanding of students’ learning from the constructivist perspective and this attribute of PCK was yet to be developed.
Findings from the analysis of the teachers' survey questionnaire, interviews with Kaudry and lesson observations reveal that Kaudry believes that science is a way of studying and developing understanding about the natural world, a 'process of producing things' and that knowledge of science keeps changing and improving. He believes that people study science in order to be able to solve problems and contribute to society. Kaudry believes that science curriculum should emphasise both content knowledge and inquiry in science; however, his teaching practices did not include any inquiry strategies.

Kaudry believes that the Lagos State’s Integrated Science curriculum is comprehensive, has achievable objectives and is flexible enough to enable him use various teaching methods. However, he believes that the document is neither current nor relevant enough to students' needs. For science teaching to be effective Kaudry believes that the teacher must take control of the class, must have good knowledge of the subject matter, should be able to explain and demonstrate the concepts and allow the students to take part in the teaching-learning process. Kaudry believes that students’ roles in effective science learning should include listening, answering questions, taking down notes, observing the teacher's demonstration and taking part in group/individual assignments. He believes that students are assessed in school in order to know their academic achievement, promote them to the next class, and give their parents feedback and to adequately prepare them for their external examinations.

Kaudry's pedagogical beliefs are consistent with knowledge transmission teaching pedagogy. He rarely engaged his students in meaningful learning or constructivist-compatible activities in the majority of the lessons observed. Kaudry’s teaching was characterised by transmission teaching style, dominated by teacher-talk, teacher demonstration, in which he gave all the information, emphasised the learning of facts in science and in which the students played the role of relatively passive receivers of knowledge. He felt concerned that the performance of the students in their final examination had continued to decline from about 85% to the current level of about 65% and might decline further.
Kaudry's classroom practice reflected a general PCK associated with class control, discipline and lesson note preparation. It also reflected PCK components or attributes derived from the traditional, knowledge transmission perspective. For instance, he employed pedagogical strategies that were driven by teacher-talk in which he sought to transfer his thoughts, meaning and information to the more or less passive students as receivers of knowledge. He gave all the information and provided detailed explanation about science content for his students in a highly controlled classroom environment in keeping with his beliefs.

His beliefs in knowledge transmission pedagogy seem to have a profound effect on his pedagogy. Because of his beliefs he made few efforts to elicit students’ representations and was unaware of how students were making sense of what they were to learn. He did not react to most of the students’ responses and maintained a distance from them. By maintaining a distance from his students and relying on transmission of facts Kaudry was not conscious about his failure to anticipate probable misconception and to address them during the lessons.

In addition, he did not encourage student interaction to facilitate their learning because he believed that he needed to have control over coverage of content to ensure efficient learning and maintain high standards. Nevertheless, from the perspective of his roles as a traditional teacher, his pedagogy reflected a PCK with some blending of knowledge of content and an understanding of context. Knowledge of students’ learning from the constructivist perspective did not reflect as an attribute of his PCK.
CHAPTER 8: DISCUSSION

The primary purpose of this study was to investigate Nigerian science teachers' beliefs about effective science teaching, their pedagogical content knowledge, and how these influenced their science teaching. The study focused specifically on Lagos State science teachers' beliefs concerning effective science teaching, their knowledge base for science teaching, how they taught and the reasons why they taught the way they did, and factors which limited the effectiveness of their science teaching.

Data generated from the teachers' survey and the three case studies were presented in Chapters 4 to 7. In this Chapter, there are discussions about the teachers' views about why science is taught in the schools, the nature of science, science teaching and learning, and assessment practices. Characteristics of the teachers' teaching behaviour and pedagogical content knowledge are also discussed in this Chapter. Findings about the teachers' espoused beliefs are drawn together into themes, which represent a consensual picture of their views.

Teachers' Beliefs

Why Science is Taught in Schools

The teachers involved in the case studies in this investigation gave various reasons for science teaching in secondary schools. Their reasons included: to enable students to gain understanding of the environment and the world; to produce science-related professionals and leaders of tomorrow; and to help students become scientifically literate individuals. Although the teachers held divergent views in some respects, the majority of them shared a common view that science is taught in schools in order to produce science-related professionals. The following assertions were developed from the case study data regarding the teachers' professed beliefs about the purpose for science teaching and learning in the schools.

Assertion 5.3
Tello believes that science is taught in schools so that students can have knowledge of the realities of the natural world and to prepare them for science-related professions.
Assertion 6.2
Angy believes that science is taught in schools in order to make students literate in science, create awareness about what happens in the environment and prepare the individuals for science-related professions.

Assertion 7.2
Kaudry believes that science is taught in order to produce science professionals, so that some people can become future leaders, and the science curriculum should emphasise both content knowledge and inquiry in science.

Tello gave reasons for teaching science that seem to be related to his traditional science teaching practice. His view that science is taught so that students can have knowledge of the realities about the natural world is reflected in his teaching practices in which he often gave information of factual knowledge in science to students. He alluded to this when he reiterated his belief in a knowledge transmission philosophy: “to be effective means... doing the right thing in the classroom, i.e. the teacher is giving knowledge out to the students and the students are ready to take...” (Interview with Tello, 28/2/02).

Angy on the other hand, believes that science is taught in order to make students literate in science, create awareness about what happens in the environment, and to prepare the students for science-related professions.

Angy’s view about scientific literacy is reflected in her instructional practices in which she organised information around conceptual clusters of problems and questions and tried to engage students’ interests, assisting them in developing new insights which they can connect to their previous learning. She seems to emphasise a general form of education in science, a general understanding about science rather than facts in science. She is also of the view that science in schools can help prepare students for science-related professions. The third case study teacher, Kaudry espoused beliefs that the purpose for science teaching in school is to produce science-related professionals and future leaders. Kaudry’s view on this issue is also related to his traditional teaching and assessment strategies already presented in Chapter 7; he probably uses assessment for the purpose of selecting students for further studies in science so as to prepare them for science-related professions and to become future leaders.
Most science educators agree that the main purpose of science teaching is to produce scientifically literate citizens (Bybee, 1993). There are countries, for example, the United States, United Kingdom, Canada and Australia, that have defined their various perspectives of scientific literacy in terms of specific skills and knowledge required of a scientifically literate individual. This helps focus the curriculum and teaching activities on the desired goal of scientific literacy.

The United State's National Science Education Standards (NRC, 1996) defines scientific literacy as the knowledge and understanding of scientific concepts and processes required for personal decision-making, participation in civic and cultural affairs and economic productivity. The document further explains that:

Scientific literacy means that a person can ask, find, or determine answers to questions derived from curiosity about everyday experiences. It means that he/she has the ability to describe, explain and make predictions about natural phenomena. Scientific literacy entails being able to read with understanding articles about science in the popular press and to engage in social conversations about the validity of the conclusions. Scientific literacy implies that a person can identify scientific issues underlining national and local decisions and express positions that are scientifically and technologically informed (NRC, 1996 p. 30).

The OECD/PISA (1999), in its operational definition of scientific literacy states:

Scientific literacy is the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activities (p. 60).

The United Kingdom's Beyond 2000 Report (Millar & Osborne, 1998) also views scientific literacy in terms of what people need to be able to do as a result of science education. The report states that "citizens should be able to: be engaged in informed discussion about scientific controversy; evaluate the significance of scientific
information; understand and interpret data; and understand scientific methodology and processes” (p. 10).

In Canada, scientific literacy has been defined as “an evolving combination of science-related attitudes, skill and knowledge students need to develop inquiry, problem solving and decision-making abilities, to become lifelong learners, and to maintain a sense of wonder about the world around them” (Ryder, 2001, p. 5).

Presenting their perspective of scientific literacy in Australian schools, Goodrum, Hackling and Rennie (2001), state:

scientific literacy is the capacity of persons to be interested in and understand the world around them, to engage in the discourses of and about science, to be sceptical and questioning of claims made by others about scientific matters, to be able to identify and draw evidence-based conclusions and to make informed decision about environment and their own health and well being (p. 15).

These countries have defined the attributes of a scientifically literate person and this gives direction to the skills and knowledge that should be taught in their secondary schools to achieve scientific literacy.

The Nigerian National Curriculum for Junior Secondary Schools outlines the purpose of teaching Integrated Science in terms of making students aware of what science is and how scientist work and does not explicitly define the skills and knowledge associated with scientifically literate individuals (Federal Ministry of Education, 1982). Among other things, the document states:

The Integrated Science teaching in the schools is intended that the student gains the concept of the fundamental unity of science; gains the commonality of approach to problems of scientific nature; is helped to gain an understanding of the role and function of science in everyday life and the world in which he/she lives (p. 3).

The purpose of science education as defined in the Nigerian curriculum seems to focus on developing understandings of the nature of science, which is quite different from scientific literacy where the focus is on developing understanding and skills to help
citizens lead more productive lives. If the description of what secondary science education is aiming to achieve had been explicitly defined in the curriculum in terms of what is expected of a scientifically literate individual, and how it should be achieved, the teachers would probably have been more focused in their ideas about the purpose for science teaching.

In the case studies, Tello and Kaudry appear to have a narrow view about the purpose of junior secondary science teaching. Such narrow views would not help students achieve scientific literacy and may have underpinned their traditional teaching styles in which they were giving isolated facts to students and acted as information-givers to more or less passive students. Their ideas about science teaching and learning in the schools seem to be consistent with the traditional paradigm in which science education is viewed as primarily preparing students for post-secondary and higher studies. The teachers’ ideas that science is taught in order to prepare students for science-related professions or to produce future leaders seem related to a traditional view of science for an elite, rather than provision of scientific literacy for all students. They seem to hold an elitist view of the general goal of science education and science curriculum, which gives little consideration to the needs of the majority that may not study science beyond the secondary level but need to be scientifically literate.

Fensham (1997) explains why teachers hold onto the elitist ideas. He explains that the narrow discipline-based science courses at the upper secondary schools have served well the current leaders of science education, including academic scientists and science teachers, so it is not surprising that they may resist change to broader science courses that focus on social and environmental issues which they perceive will dilute the rigour of the discipline of science. This corroborates the growing amount of literature which suggests that the beliefs that teachers hold impact on their perception and judgements and that these in turn affect their classroom behaviour (Ashton, 1990; Buchmann, 1984; Cole, 1989; Goodmann 1988; Clandinin & Connelly 1987).

It is the view of this Researcher, that what is important is not that students should be able to remember and recall solely a large body of scientific facts, but that they should understand how science works and how it is based on the analysis and interpretation of evidence. Students should be able to use their knowledge of science to help themselves in everyday life. The current Nigerian science curriculum seems to focus too much on
knowledge of facts in science which, in turn, has been over-emphasised in assessing students in the school system. It might need to be revised to explicitly define the skills and knowledge associated with scientific literacy as do other countries. Among other things, it should define that students be taught about how scientific ideas are presented and evaluated (e.g. in publications); ways in which scientific work may be affected by contexts in which it takes place (e.g. social, historical, moral and spiritual); and how the contexts may affect whether or not ideas are accepted; and limitations of science in addressing industrial, social and environmental questions including the kinds of questions science cannot answer, uncertainties in scientific knowledge, ethical issues and so on (Ryder, 2001).

General Assertion 8.1
The consequence of not having a Nigerian perspective of scientific literacy defined in terms of specific skills and knowledge required of a scientifically literate individual, may perpetrate the teachers’ narrow, elitist view of science teaching in which they limit science teaching and learning to the traditional purpose of preparing students for higher studies.

General Assertion 8.2
The existing curriculum, which emphasises factual knowledge, must be made more flexible to accommodate a range of skills and understandings associated with scientific literacy.

The Nature of Science
Evidence from this investigation reveals that Lagos State science teachers have narrow views about the nature of science. The following assertions regarding teachers' beliefs about the nature of science were developed from the survey and case studies.
Assertion 4.3
Teachers' responses to statements about the nature of science indicate that they believe that science theories are revised as new evidence is generated, and that science is more of a collection of facts about nature rather than a way of investigating and developing understanding about the natural world.

Assertion 5.1
Tello believes that science is a study of "concrete things or phenomena" which exists in the natural world and that science is a collection of facts about those things.

Assertion 6.1
Angy believes that science is a process of doing (producing) things, and of investigating and developing understanding about the natural world. She views scientific knowledge as dynamic and useful for solving problems.

Assertion 7.1
Kaudry believes that science is a process of doing (producing) things; a process of developing understanding about the natural world and that scientific knowledge is always improving.

Understanding the nature of science has been an objective of science instruction since the beginning of the first decade of the past century (Central Association of Science and Mathematics, 1907). The nature of science refers to the characteristics that distinguish science from other ways of knowing; "the characteristics that distinguish basic science, applied science and technology, the processes and conventions of science as a professional activity, and standards which define acceptable evidence and scientific explanations" (AAAS, 1993, p. 10). While scientists and science educators have not
agreed on a single definition of the nature of science (Lederman & Niess, 1997), the literature generally refers to the values and assumptions inherent in the development and interpretation of scientific knowledge (Lederman, 1992).

The science teachers involved in this investigation do not have a complex understanding of the nature of science. Even though the majority of the teachers (97%) agree or strongly agree that science theories are revised as new evidence is generated and that scientific knowledge is dynamic (55%), they also view science as a collection of facts about nature (87%). A good number of the teachers (39%) also hold the view that science is a study of “concrete or realistic things” rather than a way of investigating and developing understanding about the natural world (Table 4.6). Overall, the findings indicate that the teachers have a narrow understanding about the nature of science, and focus on science as being a body of knowledge.

The current view of the science community is that science is a dynamic process of investigating and developing understandings about the world, a process that neither seeks knowledge of truth or facts nor produces certainties or absolute facts about the world, and that science theories are revised as new evidence is generated (Cobern, 1996; Dawson, 1997; McComas, Clough & Almazroa, 1998). The Nigerian National Curriculum for secondary schools describes science as a way by which the child can be helped to gain an understanding of the world in which he/she lives and how scientists work (FME, 1982). The United States’ Benchmarks for science literacy (AAAS, 1993) and the National Science Education Standards (NRC, 1996) have a strong emphasis on the nature of science as a common theme; they view appropriate knowledge of the nature of science as an educational goal and an aspect of scientific literacy. McComas, Clough, and Almazroa (1998) assert that a better knowledge of the nature of science by teachers will enhance, among other things, an understanding of science and its limitations; interest in science and science classes; social decision-making and instructional delivery.

Any significant misunderstandings that students and teachers hold regarding the nature of science could be particularly damaging to general scientific literacy because they affect students’ attitudes towards science and science teaching, and that clearly has an impact on students’ learning (Tobias, 1990).
The teachers' narrow views about the nature of science seem to be consistent with their traditional teaching styles in which the emphasis is mainly on the transmission of knowledge of facts in science. These are not in keeping with current understanding about science and science teaching and may indicate lack of recent professional development. Even if the nature of science is not taught explicitly in the classrooms, science teachers need to help students realise how the scientific processes are used to acquire new knowledge. The best way for them to do this is to spend time using scientific inquiry, experimentation, discussing data, drawing inferences based on data, and writing conclusions. These processes should form the basis of Integrated Science teaching and learning in the schools. It is also desirable that students be aware of past scientific work that formed the basis for the development of present theories, and the fact that scientific theories are built on the sequential work of many scientists over time.

**General Assertion 8.3**

Science teachers need to have a complex understanding of what science is, in order to help students achieve scientific literacy.

**General Assertion 8.4**

The teachers' narrow view of the nature of science appears to influence their emphasis on factual knowledge rather than science processes and skills in their teaching.

**Teachers' Beliefs about their Roles**

Most of the science teachers surveyed, including those involved in the case studies, expressed beliefs about effective science teaching and learning which are in keeping with teacher-centred, traditional teaching styles. Findings from the case studies and particularly from classroom observations indicate that most of the teachers believe in teacher-centred teaching strategies which are dominated by telling, explaining and student listening. This is at variance with best practices in science teaching and learning. Based on the survey and case study data, the following assertions were developed regarding teachers' professed beliefs about their roles when science teaching and learning is effective.
Assertion 4.18
For effective science teaching, the majority of the teachers believe that the concept should be effectively explained, illustrated and demonstrated, and to be able to do this teachers need a good knowledge of subject matter.

Assertion 5.4
Tello believes that for science teaching and learning to be effective the teacher must have good knowledge of subject matter and should be able to explain, illustrate and demonstrate the concept being taught and should possess the ability to prepare students' minds for learning.

Assertion 6.3
Angy believes that for science teaching and learning to be effective both the teacher and students should be engaged in the teaching-learning activities that the teacher should be able to explain, demonstrate the skills involved, guide the students to perform hands-on activities and practice skills on their own, and encourage them to ask questions.

Assertion 7.3
Kaudry believes that for science teaching and learning to be effective the teacher must take control of the class, have a good knowledge of the subject matter, be able to explain, illustrate and demonstrate the concept being taught, and should allow the students to be part of the teaching-learning process.

Most of the teachers believe that science teaching is effective when the teacher demonstrates and effectively explains the concept being taught and relates it to students' lives (Table, 4.20). The responses indicate that the majority of them hold beliefs
consistent with knowledge transmission pedagogy. Nevertheless, a minority do believe in more student-oriented strategies; that teachers should allow students to learn science by doing (29%) and allow students to participate in lessons (15%). The teacher-centred views of teaching were also reflected in the teachers’ responses when they were asked to describe their last Integrated Science lessons. Most of the lessons were dominated by teacher activities of explaining (62.2%); demonstrating (29.2%) and giving examples (23%), while students played mainly passive roles of listening and taking notes. The case studies of Tello and Kaudry revealed that they hold traditional views, which are consistent with the teacher-centred teaching styles and this was reflected in their classroom teaching practices. Angy’s beliefs and classroom teaching practices were more student-oriented.

Teacher-centredness in which teaching activities are dominated by explaining; illustrating, demonstrating and giving notes are not in keeping with the current understanding about effective science teaching and learning. Contrary to the teachers’ views regarding teachers’ roles when science teaching and learning is effective, telling is not teaching and cannot bring about effective learning (Gillani, 1994). Bickman (1992) asserts:

to have knowledge is to make it, to construct it, not to record, absorb or memorise it; teaching is not simply telling (p.5).

Current understanding about effective science teaching is that instructional strategies should more actively engage students in learning and help them acquire skills, critical thinking and problem solving abilities in science. Knowledge is not passed intact from a knower to the learner, but is actively constructed by learners who use existing knowledge to interpret new information before integrating newly constructed knowledge into long-term memory in ways that expand their knowledge and influence consequent learning (Brophy, 2001).

The teacher has a central role in orchestrating the oral and written classroom discourse in ways that contribute to students’ understanding of science. An aspect of the teacher’s role in effective science teaching is to provoke students’ reasoning about science, noting that some students, particularly those who may have been used to or successful in more traditional science classrooms, may be resistant to talking about their ideas or reasoning together about science with other students. Teachers can do this by providing appropriate tasks and questioning tactics. For example, he/she may follow students’
statements with, “Why?” or by asking them to explain in their own words. Doing that consistently, irrespective of the correctness of students’ statements, is an important part of establishing a science discourse centred on scientific reasoning (Hassard, 2000).

Angy’s beliefs about effective teaching are more consistent with the constructivist view. She believes that both the teacher and the students should be involved in the teaching-learning process and that students should be guided to perform hands-on activities. Her beliefs about students’ participation during lessons was reflected in her teaching in which she tried to encourage student reasoning by the way she elicited their ideas through follow-up questions like: “Why?” “Can you explain?” or “Who has other ideas?” (Reported in Chapter 6).

At all stages of classroom teaching, teachers are to guide, focus, challenge, and encourage student learning (Yager, 1991). Effective teachers are skilled observers of students, as well as knowledgeable about science and how it is learned. Effective teachers match their actions to the particular needs of the students, deciding when and how to guide, when to demand more rigorous grappling by the students, when to provide information, when to provide particular tools, and when to connect students with other sources (NRC, 1996; Yager, 1991). Science teaching and learning is more effective when teachers continually create opportunities that challenge students and promote inquiry by eliciting their ideas and their questions.

Contrary to the teachers’ ideas about their roles for effective teaching, current theory supports the fact that science teachers should be active in different ways from that in the traditional teacher-dominated classroom. Instead of doing all the talking, the teacher should encourage the students to discuss ideas more. Teachers must do more listening and students more reasoning. Beyond asking clarifying or provocative questions, teachers should occasionally provide information and guide students, and be able to make decisions about when to let students struggle to make sense of an idea without direct teacher input, when to ask leading questions, and when to tell students something directly. They should be able to judge when students should discuss in small groups and when the whole group is the most useful context. For example, whom to call on, when and whether to call on particular students who do not volunteer. Such decisions are crucial for effective science teaching and may depend on the teacher’s understanding of science content and pedagogy, particular students and how students learn.
For effective science teaching and classroom discourse, the teacher should monitor and organise students’ participation. The teacher should be able to monitor students who volunteer comments and those who do not, how students respond to one another, what they are able to record or represent on paper about their thinking and in what contexts. Although the majority of the teachers involved in this study expressed their beliefs in student participation during lessons, it was neither reflected in their description of their roles in their last science lessons taught nor was it reflected in Tello and Kaudry’s teaching practices. However, Angy involved her students in learning activities in most of her lessons. The teacher should be able to engage every student in contributing to the thinking of the class, using a variety of means.

The beliefs espoused by the teachers about their roles in an effective science teaching, and their teacher-centred traditional teaching styles, could be challenged by professional development.

**General Assertion 8.5**

The teachers’ beliefs that the teacher should play teacher-centred roles of explaining, illustrating and demonstrating concepts, are not consistent with best practices in science teaching and learning.

**Beliefs about Students’ Roles**

The teachers in this study believe that for science teaching and learning to be effective, the students should play mainly passive roles of listening, answering questions and taking notes. Almost all the teachers (92%) involved in this investigation agree or strongly agree with the statement that a quiet class is needed for effective science teaching and learning, and that it is the teacher (not the student) who should decide what activities are to be done during lessons (71%). The following assertions about teachers’ beliefs regarding students’ roles in an effective classroom were drawn from the survey and case study data.

**Assertion 4.16**

The teachers’ descriptions of the role of students during their last lesson indicate that in the majority of the lessons students were mainly performing passive roles of listening, answering questions and taking down notes.
Assertion 5.5
Tello believes that students are to listen, observe, ask/answer questions, participate in all activities during lessons and be able to read ahead of lessons.

Assertion 6.4
Angy believes that students learn best when they feel free to interact with each other and the teacher, ask and answer questions, learn by carrying out hands-on activities, and are adequately supervised.

Assertion 7.4
Kaudry believes that students should listen in the classroom, observe the teacher’s demonstration, ask/answer questions and take down notes.

Although the majority of the teachers (52%) indicated they believe in the importance of student engagement in class activities, this view was never reflected in their description of the roles played by students during their last Integrated Science lessons. The majority of the responses (Table 4.8) referred to students’ passive roles of listening (43%) and just answering questions (36.9%). The students in the case study classes played mostly passive roles of listening, answering questions, observing the teacher, and copying notes in most of their lessons. The contrast between the teachers’ professed beliefs in students’ engagement and students’ passive roles during their last lessons raises the question of whether they were not guided by their pedagogical beliefs during the lessons described or were constrained by school factors such as large classes or lack of facilities. Indeed, people may state (and actually believe) that they believe in one thing but act in a different way. This Researcher, however, views the teachers’ idea about students’ engagement to mean paying attention during lessons i.e. listening, responding to questions, and copying notes, which is consistent with their espoused beliefs that a quiet class is necessary for effective science teaching and learning.
Tello and Kaudry hold similar beliefs to those of the majority of the teachers regarding students’ roles during lessons; that students are to listen, observe the teacher’s demonstration, answer questions and take down notes. These beliefs that are consistent with the traditional teaching method (Hanley, 2001) are reflected in their teaching practices in which classroom activities are dominated by telling and listening.

Current understanding about students' learning indicates that “just as telling is not teaching, listening is not learning” (Gillani 1994). Telling and listening approaches tend to encourage memorisation of a set of facts and figures and does not encourage students to learn how to learn. Given the rate at which the amount of knowledge grows in today's world teachers cannot produce scientifically literate citizens through telling and listening (Appleton, 1992).

The science education literature is replete with evidence that changes in instructional behaviour can improve student learning of science (Gage & Needels, 1989; Anderson & Burns, 1989). What students learn is greatly influenced by how they are taught; decisions about content and activities that teachers engage them in, and their interactions with students, all affect the knowledge, understanding, abilities and attributes that students develop (NRC, 1996).

The teachers' belief that students should adopt passive roles is not in keeping with the curriculum they are implementing and not in keeping with the best practices in science teaching and learning. Students should be equipped with the knowledge of how to learn in an ever-changing world and this can only be achieved by adopting a more student-centred approaches, so that students can learn to collaborate, find, analyse, organise, evaluate and internalise new information in the light of their own needs based on their academic and cultural backgrounds (Gillani, 1994). Science teachers should be able to promote classroom discourse in which students' roles should not be restricted to listening, observing or copying notes. In addition, students should be made to respond to, and question the teacher and one another, use a variety of tools to reason, make connections, communicate, initiate problems and questions, and make conjectures and present solutions to problems. The teachers did not provide the environment for these to happen in their classes probably because they do not have a contemporary understanding of how students learn nor the pedagogical skills to implement more student-oriented approaches.
Research indicates that teachers' beliefs about how people learn, whether verbalised or not, often help them make sense of, and guide, their practice (Lorsbach & Tobin, 1998). Current understanding about science teaching also supports the fact that students should be encouraged to learn to verify, revise and discard claims on the basis of scientific evidence and use a variety of scientific tools. Whether working in small or large groups, they should be encouraged to play the roles of being the audience for one another's comments - that is, they should speak to one another, aiming to convince or to question their peers (NRC, 1996). Students' roles in an effective classroom as viewed by the Lagos State science teachers are in keeping with their traditional teacher-dominated and didactic teaching styles. Though they are confronted with the problems of coping with large classes, evidence from the survey and classroom observations reveal that students were not deliberately involved in hands-on learning activities either individually or in groups, in class or out of class in most of the lessons.

**General Assertion 8.6**
The teachers' beliefs that students should play passive roles indicate their lack of contemporary understanding of how students learn in science.

**Teachers' Pedagogy**

The survey and case studies indicate that most of the teachers employ traditional teacher-centred, didactic teaching strategies that are at variance with best practices in science teaching and learning. The following assertions were developed from the survey and case study data.

**Assertion 4.10**
The teachers' responses indicate that, on average, they spend more than half of 40 minutes lessons explaining concepts and giving notes to students.

**Assertion 5.9**
Tello's teaching style is characterised by teacher-centred, didactic activities involving explaining, questioning and giving notes to students and is based on knowledge of facts in science.
Assertion 7.7
Kaudry's lessons were driven by teacher-talk at a fast pace which resulted in superficial coverage of large amounts of content and rarely made use of questioning.

The survey data revealed that in a 40 minutes lesson, more than half of the time (62.7%) is spent on teacher explanation and giving notes to students. The teachers' responses indicate that only 5.7 minutes on the average is spent on whole-class discussion while small group activities takes only 2.4 minutes on the average. These are indications of a highly traditional teacher-centred and didactic classroom in which the teacher acts as information giver to more or less passive students as receivers of knowledge. Similarly, the teachers involved in the case studies (except Angy, the least experienced among them) taught mainly in a traditional manner. Their teaching strategies were dominated by didactic activities involving teacher explanations in a lecture fashion and they acted as information givers while their students remained passive most of the time. They gave most of the information at a fast pace covering large amounts of content within the time available, and gave the impression that they had to cover so much before the examinations.

Learners need time to experience phenomena, reflect on their experiences in relation to what they already know, and resolve any problems that arise. Accordingly learners need time to clarify, elaborate, describe, compare, negotiate and reach consensus on what specific experiences mean to them. This learning process must occur within the individuals and be supplemented by social interactions and discussions with others (Lorsbach & Tobin, 1998). The teachers, in the study, neither encouraged students to work together nor allowed them to share ideas and information freely with each other. Most of the classes were driven by teacher-talk, and were based on knowledge of facts in science. The teachers sought to transfer their knowledge, to passive students who were to listen, answer questions and take down notes. Such teaching strategies are in keeping with the teachers' beliefs in the transmission pedagogy and are at variance with the best practices in science teaching and learning.

Furthermore, findings from the demographic data indicate that the majority of the teachers (71%) are quite experienced; having between six and 15 years of teaching
experience. Tello and Kaudry have, respectively, had 10 and 13 years experience in science teaching while Angy had six years experience. While Angy was more student-centred in approaches, Tello and Kaudry, like the majority of the experienced teachers, seemed locked into the traditional teacher-centred approaches. The question is, why do experienced science teachers employ traditional teaching methods that are not in keeping with the current understanding about science teaching and learning? One explanation might well be that they lack the knowledge of current practices in science teaching and learning because of the lack of opportunity for further training of any sort over the years. Other likely reasons may relate to the emphasis on content in the curriculum and constraints imposed by large class sizes.

As articulated by Piaget (1969), students learn better when they can construct knowledge through inquiry and experimentation instead of acquiring facts presented by the teacher in the classroom. It is difficult for a teacher to provide that kind of environment in a traditional classroom. In a study by Angelo (1991), on students in a large class setting, it was found that only 20% of the students retained what the teacher discussed after the lecture-dominated class. Students were found to be too busy taking notes to internalise the information. Moreover, after eight minutes of the lesson, only 15% of the students were found to be paying attention. Project 2061 describes the perspectives of teacher-centred, traditional teaching method when it states:

The present curriculum in science...is overstuffed and under nourished. It emphasises the learning of answers more than exploration of questions, memory at the expense of critical thought, bits and pieces of information instead of understanding in context, recitation over argument, reading in lieu of doing...They fail to encourage student to work together, to share ideas and information freely with each other or to use modern instruments to extent their intellectual capabilities (AAAS, 1993 p. 17)

The fast pace at which Tello and Kaudry delivered most of the information might not be unconnected with the fact that they had a lot to cover within the time available. The Integrated Science curriculum might be overstuffed and to cover it, the teachers resorted to moving quickly over content in a lecture fashion so as to cover large areas within the time available. On the other hand, they may have done so because it posed fewer classroom management problems for them and therefore seemed easier; the
consequences for students notwithstanding (Ravitz et al., 2000). The Lagos State Integrated Science curriculum may need to be reviewed because the teachers alluded to the fact that it has not been reviewed for more than 15 years. It is obvious that the science curriculum coupled with the teachers' didactic and textbook-guided science classrooms in Lagos States schools does not have the potential to bring about the desired outcome of scientific literacy.

**General Assertion 8.7**
Teaching is characterised by teacher-centred, didactic approaches, involving teacher explanations that deliver factual information in a lecture fashion, which limits their students to remaining passive receivers of information.

**General Assertion 8.8**
The adoption of a traditional didactic pedagogy appears to be influenced by the teachers' beliefs about science and effective science teaching, the lack of recent professional development, the Integrated Science curriculum and limitations imposed by large classes.

**Classroom Management**

Most of the teachers hold the view that for science teaching and learning to be effective, the teacher should take control of the classroom in order to provide a quiet environment suitable for teacher explanation. The following assertions were developed from the survey and case study data.

**Assertion 4.6**
Most of the teachers believe that it is the teacher (and not the student) that should decide what activities are to be done in the classroom and that a quiet class is generally needed for effective science teaching and learning.
Assertion 7.3

Kaudry believes that for science teaching and learning to be effective, the teacher must take control of the class, have good knowledge of the subject matter, be able to explain and allow students to be part of the teaching-learning process.

As already pointed out, the majority of the teachers (92%) hold the belief that a quiet class is generally needed for effective science teaching and learning and in keeping with their traditional teaching styles, they (79%) also hold the view that only the teacher must decide what activities are to be done during lessons. They make sense of teaching from their traditional perspective in which science is viewed as a body of knowledge to be learned and that their job is to explain what they know about science to their students. The case study teachers attempt to provide the quiet environment in which students can ‘absorb’ the science knowledge efficiently as they explain, illustrate with examples and give notes to students.

Such beliefs were reflected in Tello and Kaudry’s classroom practices in which they tried to control the students in order to maintain a quiet classroom suitable for their teacher-centred, knowledge transmission teaching styles. Kaudry believes that the teacher must take control of the class for science teaching to be effective (See Chapter 7). Being a traditional teacher, he took absolute control of the class, giving no room for students’ interactions. Tello’s method of class control was a little more relaxed considering the way the students responded to his questions. As reported in Chapter 5, he made more use of questioning strategies and an atmosphere of good rapport and acceptance was reflected in his lessons. Nevertheless, the lessons were teacher-dominated; he asked all the questions and students had to respond only when asked to do so. At the other end of the continuum is Angy’s style of class control, which provided an atmosphere of good rapport, friendliness and collaborative learning for her students. Even though her lessons were slowed down because she allowed student-talk and student-student interactions, significant learning seemed to take place (Chapter 6). Kaudry and Tello seemed to exercise class control over students’ behaviour so that the class is quiet so that they can explain and cover large amounts of content in their usual lecture fashion.
Lorsbach and Tobin (1998) assert that an effectively controlled classroom, is one in which students have opportunities to interact and collaborate as they learn. Instead of managing to keep students quiet and attentive in class, a classroom might be managed to enable students to talk with one another, and utilise collaborative learning strategies. Effective teachers interact with students in a skilful manner and are generally able to create an environment of respect and rapport in their classrooms (Michigan State University, 2003). Most students learn better when they are relaxed, confident and not feeling threatened. A comfortable atmosphere makes learning more enjoyable, encourages individuality and creativity (Bonwell & Eison, 1991).

Adequate class control is often characterised by an atmosphere of friendliness and humour but rarely by a teacher's domineering control. Lack of respect and rapport can be demonstrated in many ways. Teachers may disregard or demean some students' contributions, they may use sarcasm and put-downs or they may permit students to engage in similar behaviour or be inappropriately friendly with their students. In such a class, students always feel lethargic or alienated, do not invest energy in their work, and appear to be motivated by the desire to get by, preferably with as little effort as possible. This was particularly so in most of Kaudry's lessons observed. He exercised an authoritarian control over the classes and the students were unusually quiet and apparently did not feel free to talk.

This is in contrast to a model of the teacher's role in an effective classroom developed by Rogers (1987). In Rogers' model, the teacher's role in the classroom is to facilitate growth, development and learning of the students. Rogers considers empathy as the most important aspect that must be established in the classroom environment. An empathetic teacher is one who is able to literally 'stand in other person's shoes' and understands other person's feeling and attitudes. Empathetic science teachers can 'feel' for students who have anxiety about science and understand the student who wants to learn but 'holds back' for fear of peer rejection. Acceptance and trust are concepts that convey to students that the teacher accepts each person and establishes a trusting relationship in the classroom. An authoritarian approach to class control is an important aspect of traditional teaching style observed in some of these classes, providing a quiet environment for telling and listening.
While this Researcher does not intend to play down the importance of large classes and inadequate facilities, he feels that there must be a change in orientation away from the traditional styles in which the teacher creates submissive and passive students who are just to receive knowledge, towards a more student-centred approach in which students are encouraged to participate actively in class activities and at the same time made to feel accepted. This has been found to lead to better retention, better transfer of knowledge to other situations, better motivation for further learning and better problem solving ability (McKeachie, 1994). Those who have studied the learning of science have concluded that students learn best when they are engaged in active learning, when they are guided to deal with observations and concepts and when they have the sense that they are part of a community of learners in a classroom environment that is supportive of their learning (Fraser, 1986; Fraser & Tobin, 1989; McKeachie, 1994; Tobin et al., 1994).

General Assertion 8.9

The teachers' authoritarian style of class control provides a quiet classroom for their knowledge transmission pedagogy; this does not facilitate effective learning nor does it help students develop an interest in science.

Questioning

Even though the majority of the teachers surveyed indicated that they more often ask students questions to help them relate the concept to their own experience or to elicit their ideas; this was not generally observed in the case study classes. The following assertion was developed from the survey data.

Assertion 4.12

The teachers' responses indicate that they more often ask students questions to make them relate the concepts to their own experience or to elicit students' ideas or opinions than they do so in order to know if students have done their homework or if they know the correct answer.
The survey data indicate that teachers claim to more often ask questions in order to elicit students' ideas (83%) and to make them relate what they learn to their own experience (84.6%), rather than asking questions to know if homework has been done (60%) or if they know the correct answers (63%). Such espoused beliefs are not consistent with the teacher-centredness and traditional approaches of the teachers. This is because the most frequently reported reasons for asking questions are those that would help provide the teacher with insights into their students' thinking i.e. going beyond just whether the students know the right answer. Furthermore, asking questions that elicit students' own ideas is one of the more common, and probably less difficult, ways of engendering interest and thoughtfulness in a class of students (Ravitz et al., 2000).

However, evidence from their description of their last lesson and the case studies indicate that the majority the teachers rarely make use of effective questioning in their teaching and when they do, they frequently ask low-level recall questions that seek to find out if students know the correct answer and not those that would elicit student ideas or help them relate their learning to their experience. For instance, only 1.5% of the teachers referred to questioning in the description of their strategies during their last lesson. In the case studies, Tello and Kaudry asked questions that were typically low-level recall and required short, factual responses. It is either that the teachers were trying to express what they considered as ideal reasons for asking students questions during lessons or that they actually hold the beliefs but were constrained to do so in practice. They are probably aware that asking students questions to elicit their ideas and to make them relate what they are learning to their own experience is ideal for higher cognitive or conceptual learning but is not compatible with their traditional teacher-centred teaching styles. Since they often disseminate factual information, they probably find it easier to ask questions that elicit factual knowledge from their students; questions that would help them to know if students have grasped the factual knowledge. This style of questioning may also be part of a classroom management strategy, where questions are asked to check whether students are paying attention.
Question types

Findings from the case study reveal that Kaudry rarely made use of questioning apart from the review questions he used at the beginning of each lesson to check students' memories of the previous lesson. These questions were low-level, short answer questions which were recited over a very short time. Even though Tello asked questions more often than Kaudry during lessons, the questions were also low-level, short-answer recall types and based on knowledge of facts in science. Recitation of low order, short answer questions at a fast pace was very common in both Kaudry and Tello's lessons. However, Angy did not only make more use of questioning, she also more often asked higher-level questions and often required students to explain their answers.

Wilen (1987) asserts that recitation is the most predominant form of oral discourse in classrooms which are used to introduce new material and are an effective way for students to acquire factual information. Wilen explains that recitations consist of the teacher briefly presenting the topic and then interacting with students by asking short, straightforward questions repeatedly over a short period. Carlsen (1991) and Wilen (1987) are of the view that teachers make use of recitation to maintain teacher control of the lesson and interactions. Gage and Berliner (1992) assert that recitation can be effective when mixed with lecture and presentation sessions and when varied in pace and levels. Ellis (1993) claims that many teachers do rely on low-level cognitive questions in order to avoid a slow-paced lesson, keep the attention of the students, and maintain control of the classroom.

For effective science teaching and learning, the teacher should be able to ask good questions. Asking good questions fosters interactions between the teacher and his/her students and students' understanding (Rosenshine, 1971). Wilen (1991) found that most teachers spend most of their time asking low-level cognitive questions and concentrate on factual information that can be memorised. Tello and Kaudry used such questions during their lessons. For example: Who can define the term...? Who has seen...? Who can mention...? What is the formula of...? Wilen points out that it is widely believed that such questions can limit students by not helping them to acquire a deep, elaborate understanding of the subject matter.
Factual recall questions require the students to remember specific information and rely on rote memory. Higher-level cognitive questions (also referred to as conceptualisation level questions) on the other hand are questions that require students to conceptualise and use higher order thinking or reasoning skills.

Furthermore, research findings (Redfield & Rousseau, 1981; Riley, 1986; Rowe, 1969) reveal that on the average during most lessons, approximately 60% of the questions asked are lower cognitive questions, 20% higher cognitive questions and 20% are procedural. Research (Samson, Strykowski, Weinstein & Walberg, 1987) also reveals that while the lower cognitive questions are more effective than higher level questions with young (primary level) children, and particularly the disadvantaged, increases in the use of higher cognitive questions (to 50 percent) for older students is positively related to increases in on-task behaviour, length of students’ responses, the number of relevant contributions volunteered by students, increases in student-to-student interactions, students’ use of complete sentences, speculative thinking on the part of the students and speculative questions posed by students.

Reliance on recitation of low-level questions does not encourage students to use higher order reasoning skills; it can only be effective when varied or used in combination with higher conceptual-level questions. Teachers need not limit the use of questioning to reviewing their previous lessons or to check students’ memories of previous lessons; questioning should be part of the entire teaching-learning process; it could be employed at any stage to foster students understanding or to help the teacher vary his/her strategy based on students’ responses.

**Wait-time**

Observations from the case studies reveal that the teachers (except Angy) did not allow enough wait-time after they posed questions. While Tello occasionally paused for students’ responses or allowed them complete their sentences, Kaudry rarely did. Angy more often allowed sufficient wait-time. This seems to be related to the type of questions asked; she often asked broad and open questions.

Researchers on questioning strategies (Brualdi, 1998; Morgan & Saxton, 1991) speak of two kinds of wait-time: “wait-time 1” refers to the amount of time the teacher allows
to elapse after he/she has posed a question and before a student begins to speak; and “wait-time 2” refers to the amount of time a teacher waits after a student has stopped speaking before saying anything. Research has focussed more on wait-time 1 than wait-time 2 (Brualdi, 1998) and evidence from various studies (Riley, 1986; Tobin & Capie, 1980; Wilen, 1982) have revealed the following findings: the average wait-time teachers allow after posing a question is one second or less; students whom teachers perceive as slow or poor learners are given less wait-time than those he/she views as more capable; for lower order questions, a wait-time of three seconds is most positively related to students’ achievement, with less success resulting from shorter or longer wait-times; students seem to become more engaged, interact more and perform better the longer the teacher is willing to wait for higher cognitive questions.

Only Angy seemed to allow a reasonable amount of wait-time after the majority of her questions. The other case study teachers, Tello and Kaudry allowed little or no wait-time after most questions they asked during lessons. This may have contributed to the relative higher level of student-student interactions during Angy’s lessons and probably higher student achievement.

**General Assertion 8.10**

The majority of the teachers espoused beliefs that students should be asked higher cognitive questions that would elicit their ideas or help them relate what they are learning to their own experience, however, the beliefs are not reflected in their teaching practices. They ask questions which are frequently low-level recall, that elicit factual information from students and which are in-keeping with their traditional teaching practices.

**General Assertion 8.11**

Most of the teachers make use of low-level factual questions because they find it an easy tool to help their students acquire factual information, and to enable them maintain effective control of their lessons, providing an appropriate environment for their teacher-centred teaching styles.
Practical Lessons

Findings from the survey and the case studies indicate that the majority of the teachers prescribe the procedures to follow during practicals and rarely allow students to plan their own experiments. The following assertions were drawn from the survey and case studies data.

**Assertion 4.13**
The majority of the teachers provide the students with the procedure to follow for experiments and rarely allow students to plan their own investigations.

**Assertion 4.14**
The teachers' responses indicate that in almost half of the schools involved in this study, the facilities for teaching practicals were not available or poor.

**Assertion 4.11**
During 80 minutes practical periods more than half of the period is spent on teacher-directed activities involving teacher demonstration, explanation of concepts and procedures or giving notes to students rather than on students' group/individual activities.

Most of the teachers (86%) indicate that they provide students with practical procedures to follow most of the time or all the time. The laboratory practicals in most of the schools involved in this investigation involved following procedural instructions, collecting data, interpreting it as prescribed by the teacher and submitting the practical report for grading. The students are rarely allowed to plan all or part of their own investigation. The teachers estimated that on average, they spend the greater part of the time (53%) of the 80 minutes practical class on teacher directed-activities involving
teacher demonstration, explanation of concepts and procedures and giving notes to students. They indicated that on average, students spend 22 minutes of the 80 minutes period on group activities during practical lessons. It is not apparent why the practical classes were almost as teacher-dominated as normal science lessons described by the teachers. Their responses also indicate that in a little less than half (46%) of the schools, the facilities for experimental works are very poor.

Although the pattern of data from the survey is similar in many respects to that of the case studies, they vary a little with regards to teacher-student activities during the practicals. Lesson observations showed that the students actually spent most of the time engaged in hands-on activities, while their teachers were either supervising, giving instructions, providing materials for student groups to work with, or helping groups to set up their experiments. The practical procedures were given to the students (as indicated by the survey data) and the students were supervised through the prescribed stages; taking a reading, recording data and interpreting them the way they were asked to do so. It was not easy to estimate accurately the time spent by the teacher or the students on each activity, since a number of different activities were going on simultaneously.

The practical activities were not investigatory; they were aimed at confirming or verifying facts stated in the textbook. For example, Tello’s practical lesson in which he gave the circuit diagram and other materials was on energy conversion – the light bulb in the circuit connected by the student became hot and glowed brightly giving out light, indicating a conversion of electrical energy to heat and light energy. Angy’s practical lessons could also be regarded as verification in many respects considering the information given in the practical handouts in relation to some expected results at different stages of students’ investigation. For example, colour change at end-points, expected type of curves, odour or colour of expected gas and so on were stated. However, she tried to introduce some element of investigatory approach by directing the students to vary some experimental conditions. Like the other case studies, Kaudry’s practical lesson was also verification; it was aimed at the relationship between angles of incidence and the angle of reflection using the ray of light falling on a plane mirror.
Practical work is unique in science teaching and learning. It involves students in first-hand experiences to participate in science as a way of thinking and as a way of investigation. Hackling (1998) documents that “practical investigation provides opportunity for students to practice and develop investigation skills and also gain concrete experiences of natural phenomena which provide a foundation for conceptual learning” (p. 5). However, the majority of the Lagos state secondary schools, as revealed by this study seem to emphasise carrying out routine confirmatory laboratory exercises rather than student investigation. Although the students were actively engaged in observing, measuring, recording data, communicating and probably finding meanings, which are characteristics of science inquiry (Hodson, 1990), the model is far from being investigative. Investigative inquiries are not tightly controlled by the teacher, and do not necessarily need to follow a prescribed procedure or to confirm already existing ideas. Garnett, Garnett and Hackling (1995) describe a science investigation as “a scientific problem which requires the student to plan a course of action, carry out the activity and collect the necessary data, organise and interpret the data, and reach a conclusion which is communicated in some form” (p. 27).

Several researchers have concluded that hands-on laboratory work can enhance student achievement, particularly in problem solving, creativity and attitudes towards science, but to do so, laboratories must be student-centred. They must give students opportunity to develop and conduct their own investigations (Hodson, 1990; Hofstein & Lunetta, 1982; Pibum & Baker, 1993; Renner et al, 1985; Tobin, 1990). Tobin (1986) suggests that increased student involvement in planning experiments, collecting and processing data increases achievement. Pibum and Baker (1993) recommend that science curriculum at all levels be structured to include a substantial proportion of open-ended laboratories where evaluation is not based upon a priori outcome but rather leads to a spirited discussions of the dynamics involved. Hodson (1990) sums up this point of view of hands-on science: “Perhaps the claim for its (hands-on science) motivating power would have more validity if the practical work we engage in was exciting and interesting. Often it is desperately dull. It also would have more validity if we allowed students to pursue their own investigation, in their own way” (p. 34). Evidence from research suggests that doing laboratory experiments is not enough. The experiments must be ‘real’ with no right or wrong answers, and directed at least in part by the students.
Giving the students practical procedures to follow so that they can confirm information they were given in the class or that are in the textbook are in keeping with the teachers’ traditional teaching methods. Both the practical procedures and the objectives are consistent with teacher-centredness and aid to knowledge transmission. The teachers’ ideas, from the survey data, of spending the greater part of the 80 minutes practical period on teacher-activities leaving students who are in large groups of five or six (apparently because of insufficient equipment) to spend 22 minutes on hands-on activities can only limit student achievement in science. How much knowledge or skill will each of the students in a group be able to acquire in 22 minutes? It is either that the surveyed teachers hold the erroneous belief that students learn skills by watching the teacher’s demonstration or that what they actually do in practice is better represented by the case study data in which the students were actually seen to engage in group activities for the greater part of the period, though in a prescribed fashion. It is not apparent to this Researcher however, whether the students were intentionally engaged to that extent because those case study practicals were being observed. Notwithstanding this observer effect, a common picture that emerged from both the survey and case studies data is that student learning activities in the practicals are confined to what kind of knowledge the teacher wants students to acquire and how he/she wants it acquired, restricting students achievement, particularly in problem solving, creativity and interests in science.

Although the surveyed teachers reported that insufficient laboratory materials were available for teaching practicals in about 46% of the schools, the case study teachers were not seriously handicapped by lack of materials even though their students were made to work in large groups. Laboratory equipment is necessary for a successful teaching and learning of practicals in science (Hodson, 1990); however, it is the view of this Researcher that teachers’ lack of ideas about open investigation, field exploration and so on, can make them rely unduly on laboratory materials. A significant part of the Integrated Science practical can also be taught by field exploration. Practicals relating to habitats, environment, community, for example, can be taught by open investigation or fieldwork. Only one practical lesson could be observed from each case study teacher due to time constraints, however, they were all conducted in their laboratories.

An effective practical lesson at this level of education depends largely on the teacher’s knowledge of science and pedagogical skills, his/her ingenuity and creativity. An
An effective science teacher should be able to use the equipment and facilities that were observed in the schools in combination with that which can be obtained in the environment to successfully conduct Integrated Science practicals.

**Assertion 8.12**
Most practical lessons were teacher directed exercises designed to confirm facts and principles, and these exercises complemented the teachers' transmission pedagogy.

**Assertion 8.13**
The teachers do not engage students in open investigations, and were not observed to conduct field exploration activities which are consistent with current understanding of best practices in science teaching. This may be due to lack of pedagogical skill, concern about classroom management problems or lack of understanding about the effectiveness of these approaches in teaching science.

**Assessment**

The teachers' responses indicate that assessment of students in secondary science mainly involves paper and pencil tests and it is used for summative purposes. The assertions below were based on findings from the teachers' survey and case studies regarding teachers' espoused beliefs about assessment:

**Assertion 4.15**
The teachers' responses indicate that the majority of them assess their students by giving periodic/continuous assessment tests, regular class exercises, take home assignments and by terminal examinations, and they do so more often for summative purposes rather than formative purposes.
Assertion 5.7
Tello believes that students are assessed in order to determine their academic achievement and for their promotion to the next class. He believes that assessment should involve regular tests, terminal examinations, projects and class attendance.

Assertion 6.5
Angy believes that students are assessed in order to determine their academic achievements, for reporting purposes, and for their promotion to the next class. She believes that students should be assessed in various ways provided it contributes to teaching and learning and should involve the various aspects of learning i.e. knowledge, skills and attitudes.

Assertion 7.5
Kaudry believes that students are assessed in order to determine their academic achievements, promote them to the next class, and to give feedback to parents, and he assesses his students by giving periodic tests quizzes, projects and terminal examinations.

The findings from the teachers' survey and case studies data reveal that almost all the teachers espoused similar beliefs about assessment of students in the secondary schools. For example, the surveyed teachers ranked the purposes for assessing students in schools. The highest ranked included: to test students' academic ability (115); for promotion to the next class (74); to know if the lesson objective is achieved (74); to find out if they understand concepts (62); to evaluate one's self (51). Surprisingly the least ranked was: to improve learning (3); (Table 4.16).

The majority of the teachers believe that students should be assessed through giving periodic (or continuous assessment) tests (146); regular class exercises (79) take-home assignments (75), terminal examinations (67); projects (44); assessment of skills (10) and so on (Table 4.17). The survey data also indicate that the teachers actually assess their students by giving periodic tests, take-home assignments, and terminal examinations, which are often used for summative purposes.
The teachers' responses in this study reveal that they never involve students in self-assessment and that assessment of students' learning is mainly summative and that they assess students more for the purposes of determining academic performance in order to judge which students are promotable to the next class than they do so in order to improve learning. The espoused beliefs were confirmed by the observed classroom practices of the case study teachers. Aside from questioning tactics employed by Angy and to a lesser extent by Tello, evidence of formative assessment was not evident in the teachers' classroom teaching practices.

Research evidence has indicated that the mandated continuous assessment tests procedure in the Lagos State secondary schools, in which teachers are required to carry out "at least three assessment tests per term" is by no means appropriate to adequately measure students' achievement in science. For example, in a study by Ogunjobi (2000), there was no correlation found between students' continuous assessment scores and school certificate results in Physics. Among the findings from the study are that teachers limit such continuous assessment tests to their areas of interest in the syllabus, do not always cover the entire work schedule, often set recall questions and there is a lack of standardisation and limited use of marking guides.

The purpose of continuous assessment tests in Nigerian schools is to give the teacher greater involvement in the overall assessment of his/her students, provide a more valid assessment of the child's achievement, and provide the basis for the teacher to improve his/her instructional methods (Mkpa, 1997). Findings from research (Michael & Odenu, 1998; Ipaye, 1997) indicate that because of the high ratio of students to teachers in the schools, the teachers have become apathetic towards continuous assessment; that many of them often give short, poorly constructed summative tests that are often recall questions for easy grading, so as to satisfy the rule. Black (2003) asserts that repeated tests are detrimental to higher order thinking; that it emphasises the importance of tests and encourages students to adopt test-taking strategies designed to avoid effort and responsibility. When tests pervade the ethos of the classroom, test performance is often more highly valued than what is being learned and students then begin to find ways around test-scores. Research (Ipaye, 1997) also reveals that students are rarely given feedback from such tests apart from the terminal examination results, even though the continuous assessment score is as high as 40% of the entire assessment scheme.
Angy's views corroborate the research findings; she revealed during the course of the interview that most of the science teachers have adopted "it" (i.e. the continuous assessment tests) religiously and that most of them "do what they like just to satisfy the rule." No assessments were conducted in any of the lessons observed. None of the school records or curriculum documents suggested that assessment of portfolios, projects, or any outcome-based assessments are included in the assessment schemes in the schools.

A study by Goodrum, Hackling and Rennie (2001) reveals that assessment of secondary science in Australia is dominated by written tests, which are given an average weighting of about 55% in the assessment scheme. Assignments, practical reports and other bookwork are also commonly assessed. The study also notes that the use of portfolios and work samples, assessment methods associated with outcome-based assessment, are rarely used in Australian secondary schools.

Paper and pencil testing has been, and continues to be the dominant assessment method in formal education, and acquisition of content is often the dominant goal. However, most educators acknowledge that written tests assess only a very limited range of students' abilities and may restrict the ability of capable students to express themselves in other mediums (NRC, 1996). Formal testing has also been criticised for narrowness of content, lack of match to instruction, neglect of higher order thinking in favour of rote learning, and the restrictiveness of multiple choice and standard formats (Baker, 1998; Herman, 1989; Shepard, 1990). Others claimed that the traditional testing trivialises instruction, distorts curriculum and takes up valuable teaching time (Bracey, 1989; Dorr-Bremme & Herman, 1986; Stake, 1988).

Assessment of students, formal and informal can take many forms including listening to students as they work individually or in groups. Diamond (1998) asserts that:

- effective teachers do not limit students' assessment to the traditional paper and pencil tests; they observe and listen to students as they work individually and in groups; they interview students and require formal performance of tasks, investigative reports, pictorial work, models, inventions and other creative expressions of understanding and examine portfolios of students' work...(p. 15).
Assessment is not just the measurement of achievement; it is itself an integral part of learning. Information about students' understanding of science is needed almost continuously, and at any given point during a lesson (Astin, 1991). Frequent feedback to students helps them to refine concepts and deepen their understanding; it also conveys high expectations, which further stimulate learning (Wiggins, 1997). Assessment tasks should not be afterthoughts to instructional planning; they should be built into the design of the classroom teaching.

The teachers involved in this investigation outlined their views regarding the purposes of assessing students' learning, which included: to know their academic achievement, for promotion to the next class, for giving feedback to parents and so on. Apparently, none of them expressed the view that assessment is to improve teaching and learning; they seemed to focus on assessment of learning to the exclusion of assessment for learning. Stiggins (2002) asserts that if assessments of learning provide evidence of achievement for public reporting, promotion to the next class and so on, then assessment for learning serves to help students to learn more. The crucial distinction is between assessments to determine the status of learning and assessment to promote learning. It is believed that unprecedented gains in students' achievement can be realised if the current day-to-day classroom assessment process is turned into a more powerful tool for learning (Black & Williams, 1998; Stiggins, 2002; Wiggins, 1997).

Findings from this investigation revealed that the teachers did not espouse any beliefs regarding formative assessment of students' learning; their responses and classroom practices never reflected an understanding of formative assessment and neither did components of the formative assessment appear in the lessons observed. Pointing out a disadvantage of summative assessment in relation to lower achieving students, Black (2003) states: "Lower achieving students are doubly disadvantaged by summative assessment. Being labelled as failures has an impact on how they feel about their ability to learn. It also lowers their already low self-esteem and reduces the chance of future effort and success" (p. 5). Research reveals that achievement gains are maximised in contexts where the teachers increase the accuracy of classroom assessments, provide students with frequent informative feedbacks (as opposed to judgemental feedbacks) and involve students deeply in classroom assessment, record keeping, and communication processes (Stiggins, 2002). Students' achievements are maximised
where teachers apply the principle of “assessment for learning” (Black & Wiliam, 1998 p. 140).

**General Assertion 8.14**
Assessment methods in the schools are based on short paper and pencil tests and terminal examinations and are mainly used for summative purposes; assessment of portfolios, student work, projects and attitudes are not included in the assessment schemes in most of the schools.

**General Assertion 8.15**
The teachers attitudes suggest that they are apathetic towards the continuous assessment procedures probably because of large classes, inadequate understanding about student assessment, and they do not seem to regard assessment as an integral part of science teaching and learning.

**Factors which Limit Effective Science Teaching and Learning**

The teachers identified several factors ranging from limited resources, large classes to unfavourable education policies that limit the quality of teaching and learning in the schools. The following assertion was developed from the teachers’ survey data.

**Assertion 4.21**
The five most important factors limiting the quality of science teaching that were mentioned by the teachers were: limited resources, lack of appropriate textbooks, students’ poor attitude towards science subjects, large classes, and inadequately equipped laboratories.

Of the 16 limiting factors identified by the teachers surveyed, the most frequently mentioned were limited resources, lack of textbooks, students’ poor attitude towards
science, large class sizes, inadequately equipped laboratory and unconducive teaching-learning environment. Other factors mentioned include inadequate job motivation, insufficient time for each period (i.e. short time schedule for science lessons), lack of support from parents, students’ poor background, negative influence of some cultural beliefs, and insufficient number of qualified science teachers (Table 4.22).

The case studies and the survey data corroborate each other. For example, Tello mentioned lack of science textbooks for his students, inadequate science facilities and equipment, large classes, and insufficient number of qualified science teachers as the major factors limiting science teaching quality in his school. The second case study teacher, Angy identified large classes, limited facilities, lack of textbooks, and inadequately equipped laboratory as limiting science teaching effectiveness in her school. She explained that there were three or four Integrated Science textbooks in the school library which were being shared by the entire cohort of Integrated Science students, and that only a few owned the recommended textbook. Kaudry on the other hand emphasised that certain establishments like an international market, Local Government secretariat; restaurants that were recently located in the vicinity of his school were distracting the students and rendering the school environment less conducive to science teaching and learning. Kaudry seems to emphasise social distraction rather than a noise problem.

Other factors he identified as limiting science teaching quality in his school are lack of motivation, irregular payment of science teachers’ allowance (science teachers are paid a science allowance in the state), lack of in-service training and insufficient number of qualified teachers.

On the whole, limiting factors that were mentioned most often in the case studies (i.e. identified by at least two case study teachers) are lack of textbooks, limited facilities or resources, shortage of qualified science teachers and large classes. Others are lack of in-service training programs, unconducive teaching-learning environment, and lack of motivation, poor students’ attitudes towards science and irregular payment of science teachers’ allowances.

A survey of the causes of students’ under-achievement in secondary science conducted by STAN (1992) identify several causes which include gross under-funding, inadequate
reward for teaching, overloaded syllabus, low morale, inadequate knowledge of subject matter, lack of adequate pedagogical skills, shortage of qualified science teachers, poor attitude of students towards science, overcrowded classrooms, inadequate facilities, negative influence of cultural beliefs and lack of provision of educational needs by parents among other things. Research reports by Ikeobi (1995) and Ivowi (1995) confirmed the findings of STAN 1992). Findings from a study by Jegede and Okebukola (1993) reveals that Nigerian science teachers have low levels of motivation, and that they generally perceive administrative conditions, classroom and laboratory facilities and students’ attitudes towards science to be ‘harsh’ and not supportive of their delivery of good quality science teaching.

The findings from this investigation corroborate those of research cited above and further confirm that the problems are still lingering. This Researcher also asked the case study teachers to proffer solutions to the identified factors limiting their science teaching quality. For example, Tello believes that the problems would be alleviated if the State Government would provide enough funding for the education sector so that the Local Education Districts (LEDs) can support science authors to write Integrated Science books, which can be made available at subsidised costs to the students. He is of the view that the LED should encourage the organised private sector of the economy to sponsor large-scale production of science equipment that can be made available to schools and that the government should provide adequate incentives and job motivation for science teachers, explaining that this would help retain those in the service and attract more to the teaching profession.

Angy, on the other hand, believes that classes should be split into smaller units comprising at most 40 students per class and that the government should find a way of attracting more scientists to the teaching profession. She believes that the government should involve the Parents-Teacher Association (PTA) in the provision of resource materials for science teaching and that the government should increase funding of the schools. The third case study teacher, Kaudry is of the opinion that most of the problems would be solved if science teachers are better encouraged by government and the society, motivated in their job and provided with regular in-service training opportunities. He is of the view that more science teachers should be employed and that regular payment of science teachers' allowance would serve as an incentive to attract more teachers.
This Researcher agrees with all of the suggestions made by the science teachers, however this investigation has revealed in addition, that the teachers’ lack of adequate pedagogical knowledge and skills for science teaching is a major factor limiting science teaching quality in the secondary schools. This corroborates the finding by Okebukola (1997) that most secondary science teachers were handicapped by having limited experience in using the science resources available in the schools. This Researcher believes that the problem may be solved through in-service or re-training efforts.

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<th>General Assertion 8.16</th>
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<td>The survey and the case study data corroborate each other in identifying limited resources/facilities, lack of textbooks, students’ poor attitude towards science, large class sizes, and shortage of qualified science teachers as the most significant factors limiting the quality of secondary science teaching. In addition to these factors identified, the limited pedagogical skills displayed by the teachers significantly limit opportunities for learning.</td>
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### The Teachers’ Pedagogical Content Knowledge (PCK)

Analysis of teaching practices of the case study teachers are based on the model of PCK described by Cochram, DeRuiter and King (1993), which considers PCK components of teacher’s content knowledge, pedagogical knowledge, knowledge of students’ learning and knowledge of social and physical environment in which students are learning. The detailed analyses in relation to each of the case studies are presented in Chapters 5, 6 and 7. This section discusses the components or attributes of PCK that were found in the teaching practices of the case study teachers.

#### Tello

The PCK components or attributes that were evident in Tello’s classroom practices include knowledge of science content, knowledge of context and pedagogical knowledge. From the perspective of roles, he enacted in most of his lessons observed, these attributes can be regarded as fairly developed. Even though he gave most of the information to his students in a lecture fashion, the information was accurate and
carefully organised towards achieving specific lesson objectives. For example, he demonstrated this ability as the tried to translate his understanding of energy and work, in ways that students can understand; he tried to simplify the concept of kinetic energy and work in multiple ways in his own words drawing on his understanding of context or students' background (Reported in Chapter five). He probably was conscious of the potential difficulties the students might have in understanding the concept and decided to draw examples which students are familiar with from the local environment.

The attributes of an appropriate content knowledge and that of general pedagogy were demonstrated during his second lesson which was on energy conversion (Reported in Chapter five). He was able to combine the lecture and demonstration strategies, listed main points on the chalkboard and coupled this with guided class discussions, trying to lead the students to the correct answer though quizzes and clear examples drawn from the environment. He demonstrated the ability to design specific activities to reinforce the concept taught during his lessons. For example, he was able to reinforce the concept of energy conversion by using a circuit connection to show how the chemical energy stored in a battery could be converted to heat and light. He gave the reason for involving his students in hands-on activities:

I have demonstrated how the chemical energy can produce electrical energy and heat... I did it for them and I now want them to practice how to carry out the demonstration. I think that... at the end of the activities, they will understand the concept more... (Post Observations Interview with Tello, 4/3/02).

His reasonable understanding of the relationship among topics and some ability to make connections with other content areas in some of the lessons observed suggests an attribute of adequate understanding of the lesson topics. For example, his ability to demonstrate the principle of the lever during a lesson on simple machines (Lesson 3) using simple tools like the meter rule, text book and a metal object and relating the principle to the wheel barrow, nut-cracker, claw hammer and so on exemplifies an understanding of the science and his ability to translate it into lesson content.

His ability to draw most of his examples from the students' home and school environments and relating the concepts being taught to their lives and local background
also exemplifies his knowledge of context. This was particularly demonstrated during his fourth lesson (Reported in chapter five) in which he repeatedly made reference to the students' homes, lakes and ponds around the school as examples of habitat. In keeping with his belief that "science is about concrete things in nature", his examples were drawn from concrete objects which students are familiar with. His classroom practices also reflected a general PCK associated with control and management of classroom and discipline from the traditional teacher-centred teaching perspective.

Even though students' participation was minimal in most of his lessons, he gave accurate and current information about the concepts that he taught. The explanations were logical. He was able to simplify and represent Integrated Science concepts in multiple ways in his own words; his lesson plans and practices never reflected content errors apparent to the Researcher. He appeared fluent in scientific terminologies as he tried to translate and simplify definitions in several ways for students to grasp the meaning of scientific terms. He was able to respond promptly to students' misconceptions, for instance, he promptly responded to clear the point when his class was divided as to whether the wheelbarrow was a form of machine or lever in response to a loosely structured question he had asked (Reported in chapter five), and was never observed to make evasive responses to student's questions.

However, in keeping with his beliefs about students learning, Tello assigns little responsibility to students as he described their roles in an effective classroom and this appears to have influenced his PCK. He had responded:

In an effective classroom, students are supposed to listen ... a quite environment ... for instance in a class where the teacher is explaining and demonstrating... Students are supposed to listen, observe, ask questions on areas they do not understand, while the teacher should be ready to give the answer in a precise form (Survey Questionnaire, 2.13).

This is probably why his emphasis was on teaching rather than on student learning. Again, this might be why an attribute of knowledge of students learning (from the constructivist perspective) was not evident in his classroom practice.
Because of his beliefs, Tello did not involve his students substantively during his lessons observed; class participation was minimal, neither did he allow them to make their own sense of the activities they were engaged in during most of the lessons. Tello's concern was to progress through the content of each lesson, interacting with the students to the extent that they can grasp the knowledge of facts about science being provided for them, and ensuring that he completed most of the work planned for the lesson. The main goal of the lessons seems to have proper control of his class and to cover as much content as possible within the time available.

For instance, Tello did not appear to have given enough time to treat the concept of habitat before moving to the concepts of population and population density within the time of one period (Lesson 4). Knowledge of current practices in which students' prior understanding is considered to determine the extent to which they make sense of new learning, appeared not to have been given priority or yet to be fully developed. He may have been constrained in many respects by the large classes that he had to cope with during the lessons; however, his espoused teaching philosophy, teaching practices and strategies during the lessons observed only reflected an understanding of the teacher-centred, knowledge transmission pedagogy.

Although Tello endeavoured to model good science teaching by providing multiple explanations and simplifying the concepts for students understanding, he did not require students to produce oral or written texts to make their extant knowledge known; there was no effort to ascertain whether or not some students had misconceptions about energy and work, the lever or the concept of habitat that he taught. Because of his beliefs he did not seem to consider the need to examine the ideas that students brought with them to the class.

Tello did integrate or bring together some PCK attributes like knowledge of science content, knowledge of context and knowledge of general pedagogy; however his traditional teaching strategies did not reflect a considerable development and complete integration of these attributes. Veal (1998) asserts that effective teaching represents an integration of several PCK attributes. The PCK attribute or component of knowledge of student learning (from the constructivist perspective) was not evident in his classroom practices.
General Assertion 8.17
Although Tello endeavoured to model good teaching by providing multiple explanations and simplifying the concepts for students understanding, he did not involve his students substantively during his lessons; his goals were to control the class, cover as much content as possible and maintain standards.

General Assertion 8.18
Tello tried to bring together or integrate PCK attributes like knowledge of science content, knowledge of context and knowledge of pedagogy (from a knowledge transmission perspective) during some of his lessons even though these were yet to be fully developed or integrated; however, knowledge of students learning (from the constructivist perspective) was nor evident in his classroom practice or this was yet to be fully developed.

Angy

Angy’s PCK reflected the ability to prepare lesson notes in which she carefully organised lesson content in ways that science concepts can be taught for students understanding. Her lesson notes and lesson delivery also reflected no content error apparent to this Researcher; she led the students through activities apparently designed to reinforce the concepts being taught and combined the lecture, demonstration and whole-class discussions in most of the lessons.

Her ability to extend the science of acid and bases, and laboratory indicators to incorporate pigments extracted from local flowers (Reported in Chapter six) exemplifies her understanding of the science concept and how students learn in science. Angy’s PCK also reflected the ability to address students’ misconceptions. She would lead the class to correct such misconceptions or provide the corrections when it was necessary to do so. For instance, she tactically led her student to reach a consensus about the description of the colour change which indicated the presence of starch (Lesson two) through interaction or negotiation (Reported in Chapter six). Again, the way she
handled a student's idea that "when iron stay long...they become old and ...rusty" demonstrated the ability to handle students' misconceptions and also reflected her integrated understanding of the topic, pedagogical skills and how students learn in science. Rather than give a spontaneous oral response, she responded by giving out both rusted and un-rusted iron nails and pieces of iron rods to her students to observe. She probably wanted the entire class to first of all grasp the concept of rust and then the science about the conditions necessary for rust to occur or how to prevent it from occurring. She had tactically led a whole-class discussion to focus on why iron rusts.

Angy recapitulated most of the lessons observed by synthesising ideas generated from class discussions in a logical easy-to-understand form without referring to the outline in her lesson notes. Her illustrations and analogies seemed consistent with the current understanding about Integrated Science content.

An attribute of her PCK is her ability to design practical exercises which were aimed to reinforce the concepts taught in other lessons and to improve students' learning of skills through repetitive practice of discrete skills, in keeping with her espoused beliefs that "science should emphasise learning of skills" (Interview with Angy, 8/3/02). She had designed about nine practical exercises which the student groups carried out in a weekly rotational basis. She adopted this practice as a way of managing with the very limited laboratory resources in her school (Reported in Chapter six).

Her practice also reflected a knowledge about student learning in keeping with her espoused beliefs that "students should learn science by doing activities" and that her students "learn best when they are kept busy doing class assignments or hands-on activities" (Interview with Angy, 8/3/02). She had explained:

> Sometimes they want to learn by receiving every information from the teacher...However as their teacher, I think some of us know what to do...giving them information will not help much; we are to teach them (Interview with Angy, 8/3/02).

Her espoused beliefs and teaching styles indicate that she gives consideration to a variety of ways by which students can be helped to learn, rather than just giving them information. The PCK attribute of knowledge of context was also evident in Angy's
practices. She was able to source materials from the environment; often going beyond what the school could provide for science teaching. Her comment about what she derives from the environment for her teaching exemplifies her understanding of context.

But we are able to get some things too...sometimes we don’t really make use of chemicals or reagents...What of insects, leaves, flowers...sometimes toads, lizards or fish? This environment contains a lot of these things. It is difficult but I know how to get many of them...I use my students sometimes and they are always happy (Interview with Angy, 8/3/02).

She was able to lead her students to air their views and drew examples that her students were familiar with in the environment and seemed to consider students' background as important in most of her lessons (e.g. Lessons two, four, and five). Her practice reflected a fairly well developed attribute of pedagogical skills in her clear directions and procedures in most of her lessons. She was able to simplify concepts and definitions in multiple ways as she tried to make her students understand and also model good communication.

Even though these PCK attributes or components were not yet developed substantively or yet to be fully integrated to a level consistent with effective teaching and learning in science as outlined in chapter 2, she seemed to have blended her knowledge of content, her pedagogical understanding (leading students in activities), her knowledge of context (local environment and students’ background) and her understanding of how students learn in science in a manner consistent with both her beliefs about teaching and learning in science and the context in which she worked. Furthermore, her classroom practices reflected a general PCK associated with class control and management and lesson note preparation.

General Assertion 8.19
Angy's PCK reflected some attributes of adequate content knowledge, knowledge of students learning, knowledge of pedagogy and knowledge of context even though these were yet to be fully developed or integrated to a level consistent with effective teaching and learning in science as outlined in chapter 2.
Kaudry’s practice reflected various components or attributes of PCK that are derived from the traditional teacher-centred, knowledge transmission perspective. His classroom practice also reflected a general PCK associated with classroom management, control and discipline. An attribute of his PCK is a pedagogical style that reflected a tacit understanding that science can best be taught in a quiet class (Survey Questionnaire section 3.1) in which students are in total subjection to the teacher’s authority. He demonstrated this when he reiterated:

For science teaching to be effective, the teacher must take control of the class (Interview with Kaudry, 25/4/02)

Furthermore, his teaching philosophy seems to view understanding as coming from listening and receiving explanation directly in a highly controlled environment rather than as a result of active engagement in learning activities in which meaning is intimately connected with experience. He explained his beliefs about students’ roles during the lesson:

Student are to listen, take down notes and may sometimes be allowed to ask questions (Interview with Kaudry, 25/4/02; Survey Questionnaire, 2.13).

Although, his practice appeared to be driven by his beliefs in knowledge transmission and dominated by teacher-talk, it reflected some PCK attributes of an appropriate knowledge of science content and of the context of teaching/learning. His lesson organisation seemed logical and coherent; he represented the lesson content in multiple ways and in a simplified form for students’ understanding. He gave detailed explanations of each term and concept with appropriate examples drawn from the environment. He also tried to relate the concept to the students’ lives. These attribute were particularly demonstrated during his second and fourth lessons which were on simple machines and elements and compounds respectively. Kaudry explained:
You may not realise that some of the things you use in the house... I mean... your homes are actually machines... I mean things like... knives, hoes, axes or even the wheelbarrow (Lesson Observation, 20/5/02)

He tried to represent or translate the concept of simple machines in the ways that the students would understand. He also tried to represent the concepts of element and compounds in a simplified form for students to understand drawing examples that students are familiar with in their environment. He had explained:

.....the sodium chloride i.e. your table salt and the water are not elements (wrote their formulas on the board; they are compounds because they can be broken down into simpler forms... (Lesson Observation, 12/6/02).

He also displayed the ability to design practicals to reinforce the concepts taught in his classes. His practical lesson was apparently designed to provide opportunity for his students to carry out some guided activities in a somewhat prescribed fashion in order to reinforce the concepts of light rays and reflection he had taught in previous lessons.

His ability to give detailed and accurate information and draw examples from the students' home environment and background exemplifies appropriate knowledge of content and an understanding of context. His ability to develop the relationship between the concept of simple machines and simple home tools e.g. hoes, knives, axes (Second Lesson) that may exist in his students' homes also exemplifies an attribute of adequate understanding of science content. Moreover, Kaudry was fluent, confident and coherent as he tried to translate scientific terms without referring to the textbook or the lesson notes on his table. The majority of examples he gave during lessons, analogies outlined and relationships drawn among topics reflected an integrated understanding of science content and the context of the teaching and learning.

While Kaudry's practice demonstrated appropriate content knowledge and knowledge of context, pacing and content coverage in the lessons were obviously not suitable for students; opportunities were not provided for closure and the rush to cover large areas of content without regard to student understanding created an atmosphere of boredom particularly during the second and fourth lessons observed.
Kaudry’s beliefs in knowledge transmission pedagogy and his PCK seem to have a profound effect on his practice. Because of his beliefs in knowledge transmission, he made few efforts to elicit students’ representations and was unaware of how students were making sense of what they were to learn. He did not react to most of the students’ responses and maintained a distance from them. By maintaining a distance from his students and relying on transmission of facts he was not conscious about his failure to anticipate probable misconceptions and to address them during the lessons. In addition, he did not encourage student interaction to facilitate their learning because he believed that he needed to have control over coverage of content to ensure efficient learning and maintain high standards. His beliefs that students learn by being given all the information about what they need to know; that “telling simply translates into teaching” was demonstrated in his classroom practices.

From the perspective of the roles he played as a traditional teacher, it can be inferred that Kaudry’s PCK included knowledge of content and an understanding of context, even though these attributes are yet to develop significantly or fully integrated. His PCK, however, did not include an understanding of students’ learning from the constructivist perspective or this was yet to be developed.

**General Assertion 8.20**

Kaudry’s PCK included knowledge of content, understanding of context and knowledge of pedagogy (derived from knowledge transmission perspective); however, it did not include an understanding of students learning from the constructivist perspective.

Shulman (1987) claims that teachers derive their PCK from their understanding of content, their teaching practice and from their own school experience; and that PCK is influenced by content knowledge, general pedagogical knowledge and knowledge of learners. Although scholars have different conceptualisations of PCK, all agree it differs considerably from content knowledge, and that it is developed through an integrative process during classroom practice (Van Driel, Verloop, & De Vos, 1998).

Cochran, DeRuiter and King (1993) in their revision of Shulman’s original model of PCK assert that their own version is more consistent with a constructivist perspective of teaching and learning. They described a model of PCK that results from an integration
of four major components of teachers' knowledge, which include teachers' content knowledge, teachers' pedagogical knowledge, knowledge about students' learning and abilities, and knowledge of the social and physical environment in which students are learning. This study focuses on such a model of PCK because of its relevance to the constructivist perspective of science teaching and learning which also considers teachers' knowledge of how students learn and an understanding of the environment in which they learn.

Cochran, DeRuiter and King (1993) point out the strong connection between a teacher's beliefs and his/her PCK; they assert that the teacher's level of PCK informs his/her beliefs about science teaching and students' learning, and hence informs his/her instructional decision-making. Schoenfeld (1998) asserts that teachers' beliefs about subject matter, learning process, and teaching process including the roles of various instructional strategies and about students' learning affect teachers' classroom actions and should be examined in a comprehensive model of teaching. There is a growing body of literature that suggests that the beliefs teachers hold impact on both their perceptions and judgements, and that these in-turn influence their behaviour in the classroom. Further, changing these beliefs systems is an essential part of improving both teachers' PCK and teaching effectiveness (Ashton, 1990; Brookhart & Freeman, 1992; Cole, 1989; Goodman, 1988).

As professionals, each teacher has his/her characteristic beliefs, PCK and teaching goals. Beliefs about teaching, learning and subject matter, for example, are rooted in experiences, are strongly held and difficult to change (Pajare, 1992). Similarly, PCK is characteristic of individual teachers; it relates to his/her knowledge of content, of students, of the context and pedagogy. The interactions between the teacher's beliefs (in relation to subject matter, teaching and learning), and PCK shape the characteristics of the teacher and these in turn shape what he/she does; particularly classroom teaching practice (Gray, 1999).

The relationship between teachers' beliefs and PCK is depicted in the conceptual framework of this study (see page 68) based on the work of Schoenfeld (1998), which shows that there is an interaction between teachers' beliefs, PCK and classroom behaviour and that together they shape the teacher's pedagogy.
For example, Kaudry's PCK which comprises adequate knowledge of content, teacher-centred pedagogy, traditional ideas about student learning and knowledge of context are underpinned by his beliefs about science, science teaching and learning including his beliefs in elitist purposes for science teaching, knowledge transmission pedagogy, teacher-centredness, class control and summative student assessment. His traditional, teacher-centred classroom practices are shaped by the interaction between his beliefs and PCK. His beliefs and PCK are therefore important characteristics that describe or identify him as a science teacher, which in turn give meaning to what he does in the classroom.

Gray (1999), and Pardhan and Wheeler, (1998) argue that PCK is one of the most important teacher characteristics; therefore teacher development programs should focus on it. Efforts to improve teachers' PCK through in-service or pre-service training will lead to a change in teachers' beliefs and ultimately improve teaching quality. Similarly, efforts to change teachers' beliefs through, for example, provision of in-service training, may enable teachers to acquire more sophisticated PCK and hence improved teaching quality.

A study by van Driel, Valoop and de Vos (1998) finds both support and change in teachers as a result of developing their PCK. They found through an empirical study that there might be a value to having prospective teachers study subject matter from a teaching perspective. Studies conducted by Carpenter, Fennema, Peterson and Carey (1988) and Feiman-Nemser and Parker (1990), have shown that new teachers have superficial levels of PCK; that a novice teacher tends to rely on unmodified content knowledge that is often directly extracted from the curriculum or textbook and may not have a coherent framework or perspective from which to present the information in the classroom, and low levels of PCK have been found to be related to frequent use of factual and simple recall questions (Carlsen, 1987); and that teachers having low levels of PCK struggle with how to transform and represent science concepts and ideas in ways that make sense to the specific students they are teaching (Wilson, Shulman & Richert, 1987). Wilson (1992) documents that more experienced teachers have a better overarching view of content and pedagogical knowledge on which to base teaching decisions.
This section of the investigation does not focus on attempts to classify the teachers in relation to high or low levels of PCK, but rather to understand the components or attributes of it that manifest in their teaching practices. It can be inferred from the ongoing discussion that those that rely on factual knowledge, simple recall and recitation questions possess low levels of PCK. The revelation from this study, which is in contrast to Wilson's (1992) assertion that experienced teachers have a better overarching view of content and pedagogical knowledge, is that experienced teachers, who are not current with the ever-changing knowledge and pedagogical ideas, may also have limited knowledge about effective science teaching and learning and pedagogical skills and hence limited PCK.

The majority of the teachers involved in this investigation have not had the opportunity to keep abreast of current ideas about science teaching and how students learn in science. Tello and Kaudry’s teaching practices reflect pedagogical knowledge and skills, and knowledge of student learning derived from the traditional knowledge transmission pedagogy which are not in-keeping with current understanding and best practices in science teaching and learning. Their teacher-centred practices are consistent with their beliefs in the traditional, knowledge transmission strategies and ideas about how students learn in science. Angy’s teachings practices on the other hand, included a variety of strategies, which indicate an understanding of some student-centred teaching strategies which complement her generally teacher-centred approach to science teaching and learning. Her teaching practices seems to reflect some knowledge of student learning consistent with the constructivist perspective in which students are encouraged to construct meaning from their experiences using previous understandings.

It is the view of this Researcher that teacher education programs can enhance the development of PCK in pre-service teachers by modelling and sharing teaching decisions and strategies with students both by science and education faculties. Contexts that promote active simultaneous learning about many components of teaching in science can also promote the development of PCK. The contexts provided for pre-service teachers programs should be similar to classroom environments and field-based opportunities should be incorporated into teacher programs. Field experiences may include real teaching, contacts with experienced and reflective teachers, reflection and feedback (Hausfather, Outlaw & Strehle, 1996). A teacher education program that balances attention to the process of science learning with the content of what is being
learnt can help teachers to understand better both the science content and how their students should learn. Teacher education programs in Nigeria may have over-emphasised the learning of science content without any attention to the process of learning it.

Furthermore, teacher educators need to first model approaches that lead their students to understand content deeply and to view content and process as inseparable aspects of knowledge construction (Hausfather et al. 1996). For instance, even when it becomes necessary to employ a lecture, it can begin from a group's prior experience and concerns; stories could be used to set and create contexts for understandings. This will enable teachers to gain higher level of PCK in relation to student learning and also gain the perspectives and abilities to move their own students to deeper understanding of science. Prospective teachers should be treated as learners in a manner consistent with the vision of how teachers should treat students as learners; they should be grounded in learning and reflections about classroom practices.

<table>
<thead>
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<th>General Assertion 8.21</th>
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<tr>
<td>The teachers' practices reflect accurate knowledge of content and an understanding of the social and physical environment in which their students are learning.</td>
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<th>General Assertion 8.22</th>
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<tr>
<td>Tello and Kaudry's teaching practices reflect pedagogical ideas and knowledge of student learning consistent with the traditional knowledge transmission pedagogy that are in keeping with their teacher-centred beliefs.</td>
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<th>General Assertion 8.23</th>
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<tr>
<td>The teachers' reliance on knowledge transmission pedagogy may well be due to their lack of opportunities to update their knowledge of science teaching strategies and of how students learn in science, and as a consequence possess low levels of these attributes of pedagogical content knowledge.</td>
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General Assertion 8.24
Teacher educators need to model teaching approaches that lead their students to understand science content deeply and provide teaching contexts in a manner consistent with the vision of how teachers should teach in secondary schools.

Summary

This study has revealed a situation in which the Lagos State junior secondary science teachers, within their capability, are trying to provide quality science education to their students, but are limited by their beliefs, pedagogical content knowledge and school constraints. The teachers hold narrow and elitist views of the purpose of science teaching and objectivist/realist views of the nature of science. The majority of the teachers believe in the teacher-centred, knowledge transmission pedagogy in which lessons are driven by a strict class control and teacher-dominated activities, while students are to play mainly passive roles of listening and copying notes.

The case study teachers' classroom practices demonstrate accurate knowledge of science content, however, pedagogical knowledge and skills, and knowledge of student learning derived from the traditional knowledge transmission pedagogy were evident in the case studies. Major constraints to effective science teaching in the schools include limited resources, lack of textbooks, students' poor attitude towards science, large classes, shortage of qualified science teachers, and lack of professional development.

The conceptual framework for this study, first presented on page 67 has been elaborated as Figure 8.1 to illustrate the main findings of the study.
Figure 8.1 The relationship between teachers' beliefs, teachers' PCK, limiting factors and teachers' pedagogy.
CHAPTER 9

LIMITATIONS, CONCLUSIONS AND IMPLICATIONS

Limitations

This study involved a survey of the entire 70 junior secondary science teachers from two of the 20 Local Education Districts of Lagos State, Nigeria; 65 of them completed and returned the survey questionnaire and three of these teachers were purposively selected for in-depth case study. A major limitation is that the research findings cannot be generalised beyond the two Local Education Districts covered in this investigation.

It was not possible to observe every lesson taught by the case study teachers. Unfortunately only three practical lessons (one from each case study teacher) were observed. Observation of more practical lessons would have provided a richer data and probably revealed more information in relation to whether or not the teachers engage students in a variety of practical work like open investigation, field work or field exploration and so on; even though no school records suggest that they ever did. Inferences about teachers' PCK have been derived from observations of teachers' classroom behaviour. Further observational data would have enriched the findings regarding teachers' PCK.

Conclusions

The purpose of this study was to gain insights into Lagos State's junior secondary science teachers' beliefs about science teaching and learning, their pedagogical content knowledge and how these influence their classroom behaviour. The research findings are summarised in relation to the research questions of the study.

Research Question 1: What are Nigerian junior secondary science teachers' beliefs about effective science teaching?

The case study teachers generally hold an elitist view of the purpose of science teaching and learning in the secondary schools; they shared a common view that science is taught
in schools in order to produce science-related professionals (General Assertion 8.1). For example, a case study teacher, Kaudry, is of the view that teaching science will help produce future leaders ( Assertion 7.2).

The majority of the science teachers do not have a complex understanding of the nature of science. Even though many of them agree or strongly agree that science theories are revised as new evidence is generated and that scientific knowledge is dynamic, a large majority view science as a collection of facts about nature and a good number also hold the view that science is a study of "concrete and realistic things" rather than a way of investigating and developing understanding about the natural world ( Assertions 4.3, 5.1, 6.1 & 7.1). Overall, findings indicate that the teachers have a narrow understanding about the nature of science, and focus on science as being a body of knowledge. Their narrow view of science appears to underpin their emphasis on factual knowledge rather than science processes and skills in their teaching (General Assertion 8.4).

The majority of the teachers espoused beliefs about effective science teaching and learning that are consistent with teacher-centred, knowledge transmission pedagogy. They espoused beliefs that for effective science teaching the concept being taught must be adequately explained and to be able to do this the teacher must have good knowledge of subject matter (Assertion 4.18). They believe that science teachers' roles are to explain with illustrations and examples, relate the concepts to students' lives and give notes for students to copy ( Tables 4.9 & 4.18). Their teacher-centred views of science teaching were reiterated in their responses describing their roles in their last Integrated Science lessons. Most of the lessons described were dominated by teacher activities of explaining, demonstrating, giving examples, while the students played mainly passive roles of listening and copying notes (Assertion 4.9).

The case study teachers, Tello and Kaudry also hold similar beliefs and these were reflected in their classroom teaching practices. However, the third case study teacher, Angy espoused beliefs about teaching and learning that are more student-oriented. She believes that for science teaching and learning to be effective, both the teacher and students must engage in the teaching-learning activities and that the teacher should be able to explain and demonstrate the skills involved, guide the students to carry out hands-on activities and encourage them to practice skills on their own.
The teachers also espoused beliefs regarding students' roles when science teaching and learning is most effective. Most of them believe that students should listen, answer questions and take down notes during lessons (Assertion 4.16). They are of the view that a quiet classroom is generally required for effective science teaching and learning and that it is the teacher (and not the student) who should decide what activities are to be done during lessons (Assertion 4.6).

With regard to class management, the majority of the teachers hold the belief that for effective science teaching the teacher must take control of the classroom in order to provide a quiet environment for their teacher-centred, knowledge transmission pedagogy. The teachers' notion of providing a quiet environment for science teaching and learning, and that only the teacher should decide what activities to do, are in keeping with their beliefs in the traditional teacher-centred teaching styles. They seem to make sense of science teaching from an objectivist perspective in which science is viewed as body of knowledge to be learned and that the teacher's job is to explain what they know about science-content to their students.

The majority of the teachers believe in the paper-and-pencil assessment methods, which are mainly for summative purposes. Their views are that students are assessed in order to determine their academic achievements, for making judgements about which students should be promoted to the next class, keeping records in the school and to give feedback to parents. They rely mostly on terminal examinations and the entirely summative mandated continuous assessment procedures.

Research Question 2: What are the characteristics of the science teachers' teaching behaviour?

The survey and the case studies data indicate that most of the teachers employ traditional teacher-centred, didactic teaching strategies that are at variance with best practices in science teaching and learning. In-keeping with their teacher-centred beliefs, most of the classes are characterised by teacher-dominated activities involving explaining, giving examples and giving notes to students. For instance, the survey data revealed that in a 40 minutes lesson, more than 25 minutes is spent on teacher-explanation and giving notes to students. The data indicate that only about 6 minutes on the average is spent on whole-class discussion while small group activities take two
minutes on the average (Table 4.11). These are indications of highly traditional teacher-centred and didactic classroom in which the teacher acts as information giver to more or less passive students acting as receivers of knowledge.

The teacher-centredness was reflected in the classroom behaviour of the case study teachers; their teaching strategies were dominated by didactic activities involving teacher explanations in a lecture fashion. They rushed through lessons at a fast pace, covering large amounts of content within a short time while their students often remained passive. For example, Kaudry’s lessons were driven by teacher-talk as he struggled to deliver the science content at a fast pace to his students in a lecture fashion. Tello was also locked into the traditional teaching strategy giving scientific facts, explanations and notes for his student to copy. Angy, however, combined some student-centred activities with her overall teacher-centred teaching styles. In-keeping with her espoused beliefs, she was more student-centred in her teaching. She tried to engage her students in learning activities, created a classroom environment in which students freely expressed their views and asked questions. She often employed the combination of the lecture, whole-class discussion and questioning strategies in most of her lessons observed (Assertion 6.8 & 6.9)

Both Tello and Kaudry tried to control their classrooms so as to maintain a quiet classroom suitable for their teacher-centred teaching styles. For example, Kaudry gave no room for student interaction. Tello’s class control was a little more relaxed; he asked more questions and an atmosphere of good rapport seemed to exist in most of his lessons, even though he asked all the questions and students were to respond only when asked to do so.

Although the majority of the teachers reported that they often asked questions during lessons in order to elicit students ideas, evidence from their description of their last lesson and the case studies indicate that they rarely make use of questioning in their teaching, and when they do, the questions are frequently low-level recall that seek to find out if students know the correct answer, and not such questions that would elicit student ideas or help them relate their learning to their experience. For example, Tello and Kaudry frequently asked low-level recall questions that required short, factual responses. Because they often give out factual information, they probably find it easier
to ask questions that elicit factual knowledge from their students; questions that would help them to know if students have grasped the factual knowledge.

Most of the teachers prescribed the procedure to follow during practical lessons and rarely allowed students to plan their own investigations. Science practicals in most of the schools were mainly laboratory exercises which involve carrying out procedural instructions, collecting data, interpreting it as prescribed by the teacher and submitting the report for grading.

Even though the teachers estimated that on average, they spend the greater part of the 80 minutes practical class on teacher-directed activities involving teacher demonstration, explanation of concepts and procedures and giving notes to students (Assertion 4.11), lesson observation revealed that both the teacher and students were simultaneously engaged in activities the greater part of the period. While the students were engaged in hands-on activities (in groups), the teachers were either supervising, giving instructions, providing materials for student groups to work with, or assisting them to set up their experiments and many activities were going on simultaneously. The students were usually supervised through the stages of taking readings, recording data and interpreting them.

The practical exercises were aimed at confirming existing scientific facts and principles. For example, Tello’s practical lesson was to demonstrate a conversion of electrical energy to heat and light energy; Kaudry’s was to demonstrate the relationship between angles of incidence and reflection using light rays falling on a plane mirror. While Angy, attempted to introduce some investigatory approaches by asking students to vary experimental conditions, her practical lesson was largely confirmatory in many respects considering the fact that she gave the students expected results i.e. colour change at endpoints, expected curves, odour or colour of expected gas at different stages of the exercise.

Although students were actively engaged in observing, recording data, communicating and probably finding out meanings, which are characteristics of science inquiry (Hodson, 1990), the model may not be classified as investigatory.
Assessment methods in the schools are based on short paper and pencil tests and terminal examinations. The teachers' responses indicate that the majority of them assess their students by giving periodic/continuous assessment tests, regular class exercises, take home assignments and by terminal examinations, and they do so often for summative purposes. They do not involve students in self-assessment and evidence of formative assessment was not evident in their classroom practices. No assessments were conducted in any of the lessons observed and none of the school records or curriculum documents suggested that assessment of portfolios, projects, or any outcome-based assessments are included in the assessment schemes in the schools.

Research Question 3: What aspects of the teachers' pedagogical content knowledge are manifested in their classroom behaviour?

The science teachers' classroom behaviour reflected various aspects or attributes of pedagogical content knowledge some of which have developed to varying degrees. The teachers' PCK reflected the attributes of adequate knowledge of science content and knowledge of context of teaching and learning, however, appropriate understanding of students learning from the constructivist perspective and current understanding about pedagogical skills in science were not evident in the case study teachers' classroom practices. Components or attributes of PCK found in their classroom practices are presented below.

Tello

The PCK components or attributes that were evident in Tello's classroom practices include knowledge of science content, knowledge of context and knowledge of pedagogy. From the perspective of the roles he enacted in most of his lessons observed, some of these attributes can be regarded as fairly developed. For instance, even though he gave most of the information to his students in a lecture fashion, the information was accurate and carefully organised towards achieving specific lesson objectives. He demonstrated this ability as he tried to translate his understanding of energy and work, in ways that students can understand. He tried to simplify the concept of kinetic energy and work in multiple ways in his own words drawing on his understanding of context or students' background (Reported in Chapter five). He probably was conscious of the potential difficulties the students might have in understanding the concept and decided to draw examples which students are familiar with from the local environment.
The attributes of an appropriate content knowledge and that of general pedagogy were demonstrated during his second lesson on energy conversion (Reported in Chapter five). He was able to combine the lecture and demonstration strategies, listed main points on the chalkboard and coupled this with guided class discussions, trying to lead the students to the correct answer though quizzes and clear examples drawn from the environment. He also demonstrated the ability to design specific activities to reinforce the concept taught during his lessons. For example, he was able to reinforce the concept of energy conversion by using circuit connections to show that chemical energy stored in a battery could be converted to heat and light.

His reasonable understanding of the relationship among topics and some ability to make connections with other content areas in some of the lessons observed suggests an attribute of adequate understanding of the lesson topics. For example, his ability to demonstrate the principle of the lever during a lesson on simple machines (Lesson 3) using simple tools like the meter rule, text book and a metal object and relating the principle to the wheel barrow, nut-cracker, claw hammer and so on exemplified an understanding of the lesson content.

His ability to draw most of his examples from the students' home and school environments and relating the concepts being taught to students' lives and local background also exemplifies his knowledge of context. This was particularly demonstrated during his fourth lesson (Reported in chapter five) in which he repeatedly made reference to the students' homes, lakes and ponds around the school as examples of habitat. In keeping with his belief that “science is about concrete things in nature” his examples were drawn from concrete objects which students are familiar with. His classroom practices also reflected a general PCK associated with control and management of classroom and discipline from the traditional teacher-centred teaching perspective.

Even though students' participation was minimal in most of his lessons, he gave accurate and current information about the concepts that he taught. The explanations were logical. He was able to simplify and represent Integrated Science concepts in multiple ways in his own words; his lesson plans and practices never reflected content errors apparent to the Researcher. He appeared fluent in scientific terminologies as he
tried to translate and simplify definitions in several ways for students to grasp the meaning of scientific terms. He was able to respond promptly to students’ misconceptions, for example, he promptly responded to clear the point when his class was divided as to whether the wheelbarrow was a form of machine or lever in response to a loosely structured question he had asked (Reported in chapter five), and was never observed to make evasive responses to students’ questions.

However, in keeping with his beliefs in knowledge transmission Tello assigns little responsibility to students. This is probably why his emphasis was on teaching rather than on student learning. Again, this may indicate that this attribute of knowledge of students learning (from the constructivist perspective) was not developed appreciably in his PCK.

Because of his beliefs he did not involve his students substantively during his lessons observed; class participation was minimal, neither did he allow them to make sense of their own of the activities they were engaged in during most of the lessons. Tello’s concern was to progress through the content of each lesson, interacting with the students to the extent that they can grasp the knowledge of facts about science being provided for them, and ensuring that he completed most of the work planned for the lesson. The main goal of the lessons seems to have proper control of his class and to cover as much content as possible within the time available. For instance, Tello did not appear to have given enough time to treat the concept of habitat before moving to the concepts of population and population density within the time of one period (Lesson 4).

Although Tello endeavoured to model good science teaching by providing multiple explanations and simplifying the concepts for students understanding, he did not require students to produce oral or written texts to make their extant knowledge known; there was no effort to ascertain whether or not some students had misconceptions about energy and work, the lever or the concept of habitat that he taught. Because of his beliefs and PCK, he did not seem to consider the need to examine the ideas that students brought with them to the class.

Tello did try to integrate or bring together some PCK attributes like knowledge of science content, knowledge of context and knowledge of general pedagogy; however his traditional teaching strategies did not reflect a considerable development and complete
integration of these attributes. The PCK attribute of knowledge of student learning (from the constructivist perspective) was not evident in his classroom practices (Assertion, 8.17; Assertion, 8.18).

Angy

Angy's PCK was evident in her ability to prepare lesson notes in which she carefully organised lesson content in ways that science concepts can be taught for students understanding. Her lesson notes and lesson delivery also reflected no content error apparent to this Researcher; she led the students through activities apparently designed to reinforce the concepts being taught and combined the lecture, demonstration and whole-class discussions in most of the lessons.

Her ability to extend the science of acids and bases, and laboratory indicators to incorporate pigments extracted from local flowers (Reported in Chapter six) exemplifies her understanding of the science concept and how students learn in science. Angy's PCK was also reflected in her ability to handle students' misconceptions. She would lead the class to correct such misconceptions or provide the corrections when it was necessary to do so. For instance, she tactically led her student to reach a consensus about the description of the colour change which indicated the presence of starch (Lesson two) through interaction or negotiation (Reported in Chapter six). Again, the way she handled a student's idea that "when iron stay long...they become old and ...rusty" demonstrated the ability to handle students' misconception and also reflected her integrated understanding of the topic, pedagogical skills and how students learn in science. Rather than give a spontaneous oral response, she responded by giving out both rusted and un-rusted iron nails and pieces of iron rods to her students to observe. She probably wanted the entire class to first of all grasp the concept of rust and then the science about the conditions necessary for rusting to occur or how to prevent it from occurring. She had tactically led a whole-class discussion to focus on why iron rusts.

Angy recapitulated most of the lessons observed by synthesising ideas generated from class discussions in a logical easy-to-understand form without referring to the outline in her lesson notes. Her illustrations and analogies seemed consistent with the current understanding about Integrated Science content.
An attribute of her PCK is her ability to design practical exercises which were aimed to reinforce the concepts taught in other lessons and to improve students learning of skills through repetitive practice of discrete skills in keeping with her espoused beliefs that "science should emphasise learning of skills" (Interview with Angy, 8/3/02). She had designed about nine practical exercises, which the student groups carried out in a weekly rotational basis. She adopted this practice as a way of managing with the very limited laboratory resources in her school (Reported in Chapter six).

Her PCK also reflected a knowledge about student learning in keeping with her espoused beliefs that "students should learn science by doing activities" and that her students "learn best when they are kept busy doing class assignments or hands-on activities" (Interview with Angy, 8/3/02). Her espoused beliefs and teaching styles indicate that she gives consideration to a variety of ways by which students can be helped to learn, rather than just giving them information. The PCK attribute of knowledge of context was also reflected in Angy's practices. She was able to source materials from the environment; often going beyond what the school could provide for science teaching.

She was able to lead her students to air their views and drew examples that her students were familiar with in the environment and seemed to consider students' background as important in most of her lessons (e.g. Lessons two, four, and five). Her PCK reflected a fairly developed attribute of pedagogical skills in her clear directions and procedures in most of her lessons. She was able to simplify concepts and definitions in multiple ways as she tried to make her students understand and also model good communication.

Even though these PCK attributes or components were not yet developed substantively or yet to be fully integrated, she seemed to have blended her knowledge of content, her pedagogical understanding (leading students in activities), her knowledge of context (local environment and students' background) and her understanding of how students learn in science in most of her lessons observed (Assertion, 8.19). Furthermore, her classroom practices reflected a general PCK associated with class control and management and lesson note preparation.
Kaudry's PCK reflected various components or attributes that are derived from the traditional teacher-centred, knowledge transmission perspective. His classroom practice also reflected a general PCK associated with classroom management, control and discipline. An attribute of his PCK is a pedagogical style that reflected a tacit understanding that science can best be taught in a quiet class (Survey Questionnaire section 3.1) in which students are in total subjection to the teacher's authority. Furthermore, his teaching philosophy seems to view understanding as coming from listening and receiving explanation directly in a highly controlled environment rather than as a result of active engagement in learning activities in which meaning is intimately connected with experience.

Although his practice appeared to be driven by his beliefs in knowledge transmission and dominated by teacher-talk, it reflected some PCK attributes of an appropriate knowledge of science content and of the context of teaching/learning. His lesson organisation seemed logical and coherent; he represented the lesson content in multiple ways and in a simplified form for students understanding. He gave detailed explanations of each term and concept with appropriate examples drawn from the environment. He also tried to relate the concepts to the students' lives. These attributes were particularly demonstrated during his second and fourth lessons, which were on simple machines and elements and compounds (Reported in Chapter seven). He tried to represent or translate the concept of simple machines in ways that the students would understand. He also tried to represent the concepts of element and compounds in a simplified form for students' understanding drawing examples that students are familiar with in their environment.

He also displayed the ability to design practicals to reinforce the concepts taught in his classes. His practical lesson was apparently designed to provide opportunity for his students to carry out some guided activities in a somewhat prescribed fashion in order to reinforce the concepts of light rays and reflection he had taught in a previous lesson.

His ability to give detailed and accurate information and draw examples from the students' home environment and background exemplifies appropriate knowledge of content and an understanding of context. His ability to illustrate the concept of simple
machines using examples of simple home tools e.g. hoes, knives, axes (Second Lesson) that may exist in his students' homes also exemplifies an attribute of adequate understanding of science content. Moreover, Kaudry was fluent, confident and coherent as he tried to translate scientific terms without referring to the textbook or the lesson notes on his table. The majority of examples he gave during lessons, analogies outlined and relationships drawn among topics reflected an integrated understanding of science content and the context of the teaching and learning.

While Kaudry's PCK reflected appropriate content knowledge, knowledge of context and knowledge of pedagogy (derived from the teacher-centred, knowledge transmission perspective), pacing and content coverage in the lessons were obviously not suitable for students. Opportunities were not provided for closure and the rush to cover large areas of content without regard to students' understanding created an atmosphere of boredom particularly during the second and fourth lessons observed.

From the perspective of the roles he played as a traditional teacher, Kaudry's PCK reflected knowledge of content, understanding of context and knowledge of pedagogy (from knowledge transmission perspective) even though these attributes are yet to develop significantly or fully integrated (Assertion, 8.20). His practice, however, did not reflect the PCK attribute of an understanding of students' learning from the constructivist perspective.

Research Question 4: What factors inhibit or prevent the junior secondary science teachers from achieving teaching effectiveness in science?

Of the various factors identified by the teachers surveyed as limiting their effectiveness in science teaching, the most frequently mentioned were: limited resources, lack of appropriate textbooks, students' poor attitude towards science subjects, large classes, and inadequately equipped laboratories (Assertion 4.21). Other factors mentioned are inadequate job motivation, insufficient time for each period (i.e. short time schedule for science lessons), lack of support from parents, students' poor background, negative influence of some cultural beliefs, and insufficient number of qualified science teachers (Table 4.22).
The case studies and the survey data corroborate each other. For example, Tello mentioned lack of science textbooks for his students, inadequate science facilities and equipment, large classes, and insufficient number of qualified science teachers as the major factors limiting science-teaching quality in his school. The second case study teacher, Angy identified large classes, limited facilities, lack of textbooks, and inadequately equipped laboratory as limiting science teaching effectiveness in her school. She explained that there were three or four Integrated Science textbooks in the school library which were being shared by the entire cohort of Integrated Science students, and that only a few owned the recommended textbook. Kaudry on the other hand noted that an international market, Local Government secretariat and restaurants that were recently located in the vicinity of his school were distracting the students and rendering the school environment less conducive to science teaching and learning. Other factors he identified as limiting science teaching quality in his school are lack of motivation, irregular payment of science teachers’ allowance, lack of in-service training and an insufficient number of qualified teachers.

The lack of in-service training opportunity appears to be a major factor limiting the quality of teaching. The consequence of this is their lack of contemporary understandings about science teaching and learning. The majority of them seem locked into knowledge transmission, teacher-centred teaching styles that limit students’ development of deep conceptual understandings, investigation skills and positive attitudes towards science. The limited pedagogical skills displayed by the case study teachers are capable of limiting opportunities for learning. A lack of in-service training is a major factor preventing the teachers from achieving effectiveness in their science teaching.

Research Question 5: To what extent do teachers’ classroom behaviours appear to be influenced by their beliefs about effective science teaching and by their pedagogical content knowledge?

Like beliefs, PCK is characteristic of individual teachers; it relates to his/her knowledge of content, of students, of context and pedagogy. The interactions between the teacher’s beliefs and PCK shape the characteristics of the teacher and this in-turn shape his/her classroom practice (Gray, 1999).
Tello and Kaudry are both traditional teachers and espoused similar beliefs about science teaching and learning. For example, they hold a positivist view about science, the elitist view about the purpose of science teaching and learning, believe in knowledge transmission pedagogy, and believe in an authoritarian style of class management. These characteristics (or elements of them) are reflected in Tello and Kaudry's PCK observed in their teaching practices. For instance, their classroom teaching practices reflected pedagogical ideas and knowledge of student learning derived from the teacher-centred and didactic teaching perspective that are consistent with their espoused traditional knowledge transmission beliefs. For example, because of his beliefs Tello did not involve his students substantively during his lessons; class participation was minimal, neither did he allow them to make their own sense of the activities they were engaged in during most of the lessons. His concern was to progress through the content of each lesson, interacting with the students to the extent that they can grasp the knowledge of facts about science being provided for them, and ensuring that he completed most of the work planned for the lesson. The main goal of the lessons seems to have proper control of his class and to cover as much content as possible within the time available.

Similarly, Kaudry's PCK which reflects adequate knowledge of content, teacher-centred pedagogy, traditional ideas about student learning and knowledge of context was underpinned by his beliefs about science, science teaching and learning including his beliefs in elitist purposes for science teaching, knowledge transmission pedagogy, teacher-centredness, class control and summative student assessment. His traditional, teacher-centred classroom practices are influenced and shaped by the interaction between his beliefs and PCK. Because of his beliefs in knowledge transmission, he made few efforts to elicit students' representations and was unaware of how students were making sense of what they were to learn. He did not react to most of the students' responses and maintained a distance from them. By maintaining a distance from his students and relying on transmission of facts he was not conscious about his failure to anticipate probable misconceptions and to address them during the lessons.

In addition, he did not encourage student interaction to facilitate their learning because he believed that he needed to have control over coverage of content to ensure efficient learning and maintain high standard. His beliefs that students learn by being given all the information
about what they need to know; that “telling simply translates into teaching” was demonstrated in his classroom practices. His beliefs and PCK are therefore important characteristics that describe or identify him as a science teacher, which in-turn give meaning to what he does in the classroom (General Assertions, 8.20; 8.22).

Angy on the other hand, espoused more student-oriented beliefs. She espoused the belief that students learn best by doing activities and that students should be encouraged to practice skills on their own (Assertion 6.3). Her teaching practices combined some student-centred approaches with an overall teacher-centred pedagogy and she displayed a wider range of pedagogical knowledge and skills than Tello and Kaudry. Her PCK reflects an understanding of various pedagogical approaches and knowledge about student learning. Her espoused beliefs are more student-oriented, and her teaching reflected various pedagogical skills and knowledge that student learn by doing activities. Such beliefs and PCK have shaped her teaching practices.

**Implications**

The implications arising from this study are outlined in this section. The findings from this study have implications for science curriculum planning, teacher education, professional development, and secondary science teaching in Nigeria.

**Implication for Curriculum Planning**

Secondary science curriculum reform efforts in Nigeria have not been able to profile a science-teaching purpose consistent with the provision of scientific literacy as they do in many developed countries of the world. Because the purpose of science education is very central to evaluation, a statement of purpose for science education in the curriculum should be concise, cogent and clear for the sake of any administrator, and particularly the teachers so as not to give it a variety of interpretations. Purposes of science teaching ought to have a link with educational practice; ultimately as teacher’s professional reflection deepens and experience accumulates, the link between science teaching purposes should become fully realised in observed teaching practice.

For example, the case study teachers in this study hold the view that science is taught in schools in order to produce science-related professionals or future leaders, rather than
providing scientific literacy for all. Their elitist views may result from lack of clarity
about goals in the science curriculum statement for science education.

Other countries like Australia, the United States, United Kingdom and Canada have
defined their own purposes of science teaching in terms of what scientifically literate
individuals should be able to do. It is the view of this author that the purpose of science
education as presented in the Nigerian secondary science curriculum, should be a clear
expression of national values in relation to skills and competences expected of
individuals when they are scientifically literate. It should reflect a National mission
statement; a benchmark for all science teaching activities and a reference point for all
assessments. This will give clearer direction to the science teachers, impact on their
belief systems, and over time they will align their practices towards achieving the
general goal.

Furthermore, the curriculum seems to be overloaded, content-oriented, and examination
focussed. This may have been the reason why most of the teachers adopt teacher-
centred lecture styles in order to cover the content within the available time. The science
curriculum needs to be reviewed and in doing so, the science teachers should be
involved. Ivowi (1998) documents the exclusion of classroom teachers in curriculum
planning and developments in Nigeria as a serious flaw. The curriculum’s pedagogical
intent should be outcome based, and based on student-centred and inquiry strategies, in
keeping with current understandings in science teaching and learning. However, the
challenge for teachers to navigate a transition from a content-oriented didactic syllabus
to a more student-centred and inquiry-oriented syllabus will be daunting, and calls for
serious planning and efforts on the part of the teacher educators and education
ministries.

Implication for Teacher Education

The teachers involved in this investigation emphasised factual knowledge of content in
their teaching. The teacher education programs in Nigeria need to closely examine their
own curricula to determine the extent to which they model integration of content and
pedagogy. The science and education faculties in the Universities and Colleges of
Education need to encourage cooperative learning, challenge students’ prior knowledge,
and discourage a transmission view of knowledge in their teacher training. A
A teacher education that balances attention to the process of learning with the content of what is being learned can help teachers to better understand both their content and the learning of their students. Too often content is taught without any attention to process in most of the Colleges of Education. The teacher educators must first model approaches that lead their students to understand content deeply and to view content and process as inseparable aspects of knowledge construction (Hausfather et al., 1999). This will enable prospective teachers to gain the perspectives and abilities to move their own students to deeper understandings of science. For example, lectures can be started from a group's prior experiences and concerns; stories may be used to create contexts for understandings.

The teacher education programs should be able to provide opportunities for pre-service teachers to learn within cooperative or discourse groups, providing a guide to their own teaching; they should be taught and treated in a manner consistent with the vision of how they are expected to teach their own students; they should be grounded in learning and reflections about classroom practices.

Implication for Professional Development

The demographic data reveal that 76% of the teachers (Table 4.2) involved in this investigation had at least three-year professional teaching qualifications, or at least four years of pre-service teacher education either from the Colleges of Education or from the Universities and at least six years of teaching experience. Despite their content knowledge competence and detailed lesson notes, their lesson explanations were more didactic than conceptual and their overall teaching styles remained teacher-centred and traditional. The teachers have not had the opportunity for professional development for many years and they shared a common view that lack of professional development was a factor limiting the quality of their science teaching.
Professional development is a process whereby teachers or educational professionals regularly enhance their academic knowledge and pedagogical understandings, as well as question the purposes and parameters of what they do (Braimoh & Okedeyi, 2001; Fallan, 1995). Teachers' professional development ought to be viewed as a process of renewal and change since, as the professional knowledge base expands, new types of expertise are also acquired (Fallan, 1995). Stagnation of expertise development is a common phenomenon in Lagos State schools and this may have resulted in the current shortage of science teachers because many of them have had to quit the teaching profession for more lucrative ones. Furthermore, it may well be that the shortage of science teachers in the schools is resulting from unemployment in the system; there may be many qualified science teachers out there that are not employed by Government.

Becoming an effective science teacher is a continuous process that stretches from pre-service experiences in undergraduate years to the end of professional career. Teacher development is a process of growth in expertise about teaching throughout the teacher's career. Apart from personal characteristics, factors in the working environment and external development opportunities and interventions influence teacher development.

Development interventions should link closely to the working environment i.e. the schools in order to be effective. The school-working environment is very influential in professional growth and the establishment of teaching styles and routines. Teachers' professional development efforts should involve the schools. There is ample evidence that teacher development can often best take place in the school. This form of situated learning needs school support because it will have some influence on normal classroom practice. Again, without a supportive culture, teachers' newly acquired knowledge and skills have little chance of having a lasting impact on their practice. Indeed, teacher professional development efforts should be linked with organisational development of schools or science departments in order to have far-reaching effects. Teachers are the most important influence on the emotional, moral, aesthetic and intellectual qualities of education; school improvement is closely related to teacher development.

The teachers involved in this investigation have been able to define (though in various ways) their own standards for effective science teaching and learning. While these findings may be applicable to other similar situations, this author is of the view that it would be appropriate to have a consensual agreement between teacher training.
institutions, ministries of education and the teachers themselves in relation to standards of good classroom practice. A standard for teacher certification is not synonymous with standards of what constitutes good quality classroom practice. Science teachers collectively have to be able to demonstrate their ability to define what is meant by good quality practice in relation to current understandings.

Professional development of science teachers should therefore be driven by a well defined image of effective classroom learning and teaching; provide for teachers to build their knowledge and skills; model the strategy teachers will use with their students; provide links to other parts of the education system and strive to build a learning community. The science teachers need to experience for themselves the science learning they will want their students to do. Just as students deepen their knowledge of science through communication, so too do their teachers learn through formulating, sharing, and challenging what they and their colleagues think they know.

Furthermore an urgent need exists to enhance the science teachers’ pedagogical content knowledge. Expert teachers possess excellent PCK (Harrison, 2002) and this study reveals that experience alone is no substitute for expert PCK. It cannot be taught but is learned in cooperative teaching contexts and develops as teachers use various knowledge dimensions including content knowledge, knowledge of pedagogy, knowledge of students as individuals and as social groups, learning theory, curriculum dispositions and assessment practices, to plan and implement interesting activities and explanations that challenge their students (Harrison, 2002). PCK rarely develops in isolation; teachers best develop their PCK in mentor-mentee relationships or collegial groups.

Again, teachers’ beliefs about science teaching and student learning are instrumental in defining teaching and learning tasks, in selecting cognitive tools, in planning for instruction and in adopting teaching strategies. Teacher’s personal beliefs about teaching lie in the heart of his/her teaching practices; changing such beliefs is an essential part of both professional and teaching effectiveness (Ashton, 1990; Cole, 1989). Teachers’ beliefs about science teaching and student learning can only be changed through professional development and intervention programs deliberately planned to challenge such beliefs. Because of the strong relationship between teachers’ beliefs and PCK, changing the teachers’ beliefs prepares the ground for developing their
PCK through cooperative, collaborative practices and teaching experiences. Indeed, when teachers’ beliefs are challenged, they gain more understanding about teaching and may drop their old practices; and their PCK also increases to higher levels. This will bring about better quality of science teaching and student learning.

The Lagos State science teachers plan and teach in semi-isolation; many of them seem to consider it risky exposing their teaching to scrutiny by other teachers or visitors. Any developmental intervention should encourage a culture of in-school collaboration.

The teachers obviously need to be provided with opportunity to undergo continual renewal in such a way that they change their focus and orientation away from the behaviourist view of how students learn; away from the traditional teacher-dominated method of teaching, and towards student-centred practices using the constructivist-related approaches which is not to transmit information, but rather to encourage knowledge construction and formation and development of meta-cognitive processes for judging, organising and acquiring new information (Bruning, 1995). The Local Education Districts might begin to organise seminars, workshops, and exhibitions and so on, for the teachers in collaboration with the State’s University and Colleges of Education because these institutions are particularly relevant since most of the teachers received their teacher training from them in the first place.

Implication for Science Teaching

The findings from this study indicate that understanding about how students learn can be a valuable asset to guide teacher’s instructional planning and delivery. The significance of the findings in relation to the teachers’ strategy is that most of the teachers, operating in less-than-adequate circumstances (by western standards) and within their abilities are struggling to provide a rich science education for students; however their efforts and creativities are blunted by their beliefs and demands for more formal, traditional teacher-centred teaching geared towards examination performance.

Again, teacher-centredness in science teaching is not peculiar only to Nigerian secondary schools. The support for more student-centred approaches to science teaching is derived from research findings, which indicate that students achieve better in science through student-oriented teaching/learning approaches. Notwithstanding the wide
support, teacher-centredness is still employed to various degrees in secondary schools in most part of the world including the developed western world. But the TIMSS (OECD/PISA, 1999) results indicate that students from these countries are achieving better in science. It may well be that teacher-centred approach is more widely practiced in Nigerian secondary schools or that it has been compounded by other problems arising from the teachers' limited PCK, large classes, lack of professional development and limited facilities.

What students learn is greatly influenced by how they are taught; decisions about content and activities that teachers engage them in, and their interactions with students, all affect the knowledge, understanding, abilities and attributes that students develop (NRC, 1996). A more contemporary approach to teaching is to adopt classroom practices or learning activities that align with the findings of research. Teachers who use only one teaching style day after day may limit students who may learn more effectively through a variety of approaches. The common perception is that, over time, traditional lecture methods become boring to students. Telling and listening approaches tend to encourage memorisation of a set of facts and figures and do not encourage students to develop interest in learning science.

Students should be equipped with the knowledge of how to learn in an ever-changing world and this can only be achieved by adopting more student-centred approaches, so that students can learn to collaborate, find, analyse, organise, evaluate and internalise new information in the light of their own needs based on their academic and cultural backgrounds (Gillani, 1994). In addition, students should be encouraged to respond to, and question the teacher and one another, use a variety of tools to reason, make connections, communicate, initiate problems and questions, make conjectures and present solutions to problems in a risk-free environment.

Practical lessons should involve more investigative and field exploration exercises. An effective practical lesson at this level of education depends largely on the teacher's knowledge of science and pedagogical skills, his/her ingenuity and creativity. An effective science teacher should be able to use the equipment and facilities that were observed in the schools in combination with that which can be obtained in the environment to successfully conduct integrated science practicals.
Findings from this investigation revealed that the teachers did not espouse any beliefs regarding formative assessment of students' learning; their responses and classroom practices never reflected an understanding of formative assessment and neither did components of the formative assessment appear in the lessons observed. Assessment is not just the measurement of achievement; it is itself and integral part of learning. Information about students' understanding of science is needed almost continuously, and at any given point during a lesson (Astin, 1991). Frequent feedback to students helps them to refine concepts and deepen their understanding; it also conveys high expectations, which further stimulate learning (Wiggins, 1997). Assessment tasks should not be afterthoughts to instructional planning; they should be built into the design of the classroom teaching.

Research reveals that achievement gains are maximised in contexts where the teachers increase the accuracy of classroom assessments, provide students with frequent informative feedbacks (as opposed to judgemental feedbacks) and involve students deeply in classroom assessment, record keeping, and communication processes (Stiggins, 2002). Assessment of portfolios, student work, projects and attitudes should be included in the assessment schemes of the schools.

Implication for further Research

The purpose of this study was to gain insights into Lagos State's teachers' beliefs about science teaching and learning, and their pedagogical content knowledge, and how these characterise their teaching approaches, using data from the survey and classroom observations. For the sake of generalisability, this study could be replicated in other states of the federation in order to get a general picture of Nigerian science teachers' ideas about science teaching and learning, how they teach and why they teach the way they do. Again, because of the uniqueness of this type of research because of its focus on teaching-learning activities and teachers' knowledge in the classroom setting, it could be incorporated into the national research project in order to have a more comprehensive coverage of this core area of science education. Ogunleye (1996) and Ivowi (1998) document the dearth of science education research focused on classroom interaction, teacher's knowledge/aptitude in Nigeria.
While similar studies suggested above would improve the generalisability of findings from this study, more focused research can address the specific issues such as:

- Teacher preparation in the Nigerian Universities and Colleges of Education in relation to the education, science and methodology content in their teacher-training programs.
- Engaging all stakeholders including the teacher educators, ministries of education and the science teachers in developing a vision of what constitutes an acceptable quality teaching standard. Such a consensual vision of what an acceptable quality standard is, can then become a benchmark that can be looked upon in relation to the current status of science teaching and learning in Lagos State or in Nigeria as a whole.
- Assessment methods, particularly the mandatory continuous assessment procedure in relation to teachers' knowledge of assessment methods and practices.
- Student achievement (based on learning outcomes) in teacher-centred and more student-oriented classrooms, and the perception of such students of their schools and teachers.
- The impact of the current curriculum on teaching and learning.

**Contribution of this Study**

This study makes a contribution to the knowledge and understanding of beliefs about science and science teaching held by science teachers in an African setting. It also reveals understanding about their pedagogical knowledge, their classroom teaching practices and the reasons for adopting such teaching strategies. The quality of the findings is enhanced because the data sources included a survey, personal interviews, classroom observations and analysis of school documents. This triangulation of information improves the credibility of the data.

With regard to teachers' beliefs, the study reveals that the science teachers hold a narrow, elitist view about the purpose of secondary school science teaching, a narrow and realist or objectivist view of the nature of science, and a teacher-centred knowledge transmission view of science teaching.
The study reveals that the teachers' teacher-centred, didactic classroom practices are a reflection of their espoused beliefs and their pedagogical content knowledge that have not changed over the years due to lack of professional development. This investigation reveals that what the teachers do in the classroom best describes what they say they believe in; there are instances when teachers say one thing in theory or on paper and do another in the classroom reality. The Lagos State science teachers are mostly traditional teachers, employ knowledge transmission pedagogy; students play passive roles in most of their lessons; assess their students mainly for summative purposes. There are shortages of science teachers and science textbooks and the classes are large.

Finally, this study reveals that experience alone is not a panacea for higher levels of pedagogical content knowledge of teachers. Experienced teachers who are not current and reflective about science teaching and learning may become locked into the traditional knowledge transmission pedagogy and their PCK may never develop unless a retraining opportunity is provided.
REFERENCES


Tobias, S. (1990). They're not dumb; they are different: Stalking the second tier. Tucson: Research Corporation.


APPENDIX A: SURVEY QUESTIONNAIRE

Nigerian Science Teachers' Beliefs about Effective Science Teaching

INTRODUCTION:

- This questionnaire asks for your opinions about effective science teaching and learning and factors which support or inhibit your current teaching practices. The findings of this research will be used to develop recommendations to improve the teaching and learning of science in our schools.
- It should take about 20 minutes to complete the questionnaire.

- All information given by you is strictly confidential and anonymous. All responses will be aggregated and summarised, and when reported no person or school will be identified.

- No personal information gathered in this study will be accessible to your employer, school authority or anyone in this country.

- The summarised findings of the study will be made available on request to all participants.

- This study has been approved by the Ethics Committee of Edith Cowan University, Western Australia.

Thank you very much for your participation in this study

SECTION 1: BACKGROUND INFORMATION

Instructions: Please answer these questions by ticking the most appropriate response in the boxes.

Location of your school: [ ] Rural [ ] Urban
YOUR AGE: 20yrs & below 21-30yrs 31-40yrs 41-50yrs 51yrs & above

Sex: MALE. FEMALE.

4. (i) What are your academic qualification?:

NCE B.Sc. B.Ed. PGDE M.Sc. M.Ed. PhD Others:

(ii) Your major subject area in your qualification:

Integrated. Science Biology Chemistry Physics Agric Science. Others:

5. Years of Teaching Experience: 0-5 6-10 11-15 16-20 21 & above

6. This term I am teaching: Only science Mostly science Some science, but mostly (please state):

SECTION 2

Please express your views on the following questions.

2.1 Briefly describe the last Integrated science lesson you taught? (Please include what you were doing during the lesson).


2.2 What were the main teaching strategies you used?


2.3 What was/were the role(s) of the students during the lesson?

________________________________________________________________________

________________________________________________________________________

2.4 Give the reasons why you consider the lesson effective or not effective?

________________________________________________________________________

________________________________________________________________________

2.5 Was this lesson typical of the lessons you teach? (Please give the reason).

________________________________________________________________________

________________________________________________________________________

2.6 If not please explain what would be the features of a typical lesson you teach?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

2.7 For the lesson described in 2.1 briefly describe: (a) Class size:

________________________________________________________________________

________________________________________________________________________

(b) Classroom environment and facilities:

________________________________________________________________________

________________________________________________________________________

(d) The resources you used in your teaching:

________________________________________________________________________

________________________________________________________________________
2.8 In a typical 40 minutes science lesson, please estimate the time spent on the following:

(a) Teacher explaining: 
(b) Giving notes to students: 
(c) Supervising students work: 
(d) Whole class discussion: 
(e) Small group discussion: 
(f) Students reading text books: 

2.9 In a typical double period of 80 minutes practical lesson, please estimate the time spent on the following activities:

(a) Teacher demonstration: 
(b) Students' group work/activities: 
(c) Individual student's activities: 
(d) Teacher explaining: 
(e) Whole class discussion: 
(f) Giving notes to students: 

2.10 How often do you give the experimental procedures for students to follow during their practical investigations? Please tick (as it applies to you):

(a) All the time.  (b) Most of the time.  (c) Some time.  (d) Never.

2.11 How often do students plan their own practical investigation? Please tick (as it applies to you).

(a) All the time.  (b) Most of the time.  (c) Some time.  (d) Never.

2.12 How adequate are the facilities for teaching practical lessons? Please tick (as it applies to you).

(a) Very good.  (b) Adequate.  (c) Very poor.  (d) Not available at all.

2.13 I believe science teaching and learning is most effective when:
(a) the teacher does the following:

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
2.14 List four major factors (in order of importance) that inhibit or limit the effectiveness of your science teaching?

1. 

2. 

3. 

4. 

2.15 List in order of importance, the purposes of assessing students in your school? (The reasons why you assess your students).

2.16 List in order of importance, the assessment methods you normally use in science:

SECTION 3

Statements about beliefs regarding science teaching and learning are given below in a 5-point scale. Please indicate the degree to which you agree with the statements by
putting a circle round the number that corresponds to your beliefs about that

<table>
<thead>
<tr>
<th>Beliefs about science teaching</th>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>Undecided</th>
<th>Agree</th>
<th>Strongly agree</th>
</tr>
</thead>
</table>

1. A quiet class is generally needed for effective learning.  
   1 2 3 4 5

2. It is better when the teacher – not the students – decides what activities are to be done.  
   1 2 3 4 5

3. Students will take more initiative to learn when they feel free to move around the room during class.  
   1 2 3 4 5

4. Students should help establish criteria that will be used to assessed them.  
   1 2 3 4 5

5. How much students learn depends the relevance of the lesson to students' lives.  
   1 2 3 4 5

6. One of the most important factors influencing what a student learns in science is his/her existing knowledge  
   1 2 3 4 5
and beliefs about the topic.

7. Scientific knowledge does not change.

8. Science is a collection of facts about nature

9. Science is a way of investigating and developing understandings about the natural world.

10. Science theories are revised as new evidences are generated

SECTION 4

Questions a-f below are based on your desired goals in asking students questions and your level of attainment of teaching effectiveness. Please tick the appropriate response applicable to you.
SECTION 5

This section is based on your beliefs about science curriculum organisation and your integrated science curriculum in particular. Please tick the appropriate response

<table>
<thead>
<tr>
<th>My goals for asking students questions during science lessons are:</th>
<th>Never</th>
<th>Sometimes</th>
<th>Often</th>
<th>Very often</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) To see if students know the correct answer.</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>(b) To see if they have done their homework.</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>(c) To elicit the students ideas or opinions.</td>
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<td></td>
</tr>
<tr>
<td>(d) To get the students to explain their reasoning.</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>(e) To make students relate what they are learning to their own experience.</td>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

applicable to you.

<table>
<thead>
<tr>
<th>1. I believe that the science curriculum should emphasise content knowledge.</th>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>Undecided</th>
<th>Agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. I believe that the science curriculum should emphasise methods of inquiry in science.</td>
<td></td>
<td></td>
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<tr>
<td>3. I believe that the curriculum</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
4. I believe that the science curriculum should be relevant to students’ environment and lives.

5. I believe that the content of the Lagos State Integrated Science Curriculum:
   
   (a) is comprehensive.
   
   (b) is current.
   
   (c) relevant to students’ needs.
   
   (d) objectives are achievable.
   
   (e) is flexible enough to enable me use various teaching methods.

Please check if you have left out some questions.

Thank you.
APPENDIX B: INTERVIEW GUIDE

Interview Questions

Demographics

1. School:
2. Age of participant:
3. Educational qualification:
4. Years of teaching experience in science:
5. Date of interview:
6. Time of interview:

Structured Interview

- What do you believe are the characteristics of effective science teaching and learning?
  (Prompt: When a lesson is described as being effective, what are teacher’s roles? What are the students’ roles?)

- To what extent do you believe that your science teaching is effective or not effective? What do you do well? What aspects need improving?

- Please outline three most important factors which inhibit your attainment of effective science teaching and learning in your school?
  (Prompt: Can you name them in order of importance?)

- How do you think that such factors can be addressed?

- How do your students prefer to learn?

- Tell me how you assess your students?
  (Prompt: What aspects of learning do you assess and how often? What methods do you use and why?)
• What are your views regarding the nature of science?

(Prompt: How would you want your students to view science?)

(Prompt: Why do you think science is taught in the school?)
**APPENDIX C**

**Classroom Teaching Observation Guide Sheet**

Time of visit

Date of visit:

Teacher:

School:

Visit No:

Class observed:

Description of science lesson

**Focus on lesson observation:**

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher's activities</th>
<th>Students activities</th>
<th>Teacher's gestures, comments, teaching styles etc</th>
<th>Researcher's notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Table of observable teaching/learning behaviours
APPENDIX E: LETTER OF REQUEST FOR PARTICIPATION

2 Bradfords street,
Mount Lawley, WA
6050.
Perth,
Western Australia.

Dear colleague,

I am undertaking a research as part of my PhD thesis which involves a study of science teaching and students’ learning behaviour in the junior secondary level. I write this letter to seek your assistance and your consent to participate in the study which will involve interviews and classroom observation sessions.

The purpose of the study is to investigate science teachers’ beliefs about effective science teaching, classroom teaching practices and students’ learning behaviours in science. I would like to observe you teaching science for about five lessons; interview you for about 30 minutes regarding your beliefs about science teaching; and look through your curriculum document and program. I should also like you to meet with some other teachers involved in the study to discuss the findings of the research.

The following guidelines will apply to your participation in this study:

- Participation is strictly voluntary; you have the right to withdraw from the study at anytime.

- All information given by you will be confidential and will not be used for any purposes other than to gain understanding of science teaching and learning in our schools and for the purpose of this research. All information gathered from the questionnaires, observation of your lessons, from any document used by you in your science teaching or your teaching strategies will remain confidential and will not be disclosed.
- Your identity and that of your school will not be disclosed to anyone. Names of schools and that of the participants will be replaced with codes and pseudonyms respectively in order to maintain anonymity of all participants in the study.

- Any interpretations I make of your comments will be returned to you so that you can verify that they are accurate and reflect your thoughts.

- Your participation will not in anyway affect your position as a science teacher.

You are therefore invited to participate in this study. You may also be invited to take part in the second part, which will involve five science teachers.

Should you have any questions regarding this research project or any aspect of its procedures, please feel free to contact me at these addresses during the course of this study: (a) School of Science, Adeniran Ogunsanya College of Education, Ijanikin, Lagos. (b) Block 93 flat 2, Iba Estate, Ojo, Lagos. These addresses are quite close to your school.

If you would like to discuss this research with an independent person, you may contact my supervisor: Associate Professor Dennis Goodrum by phone (0011 61 89273 8677) or by e-mail (d.goodrum@ecu.edu.au).

Would you please read and complete the consent form attached to this letter.

Many thanks,

Benjamin, M. Ayinde.
APPENDIX F

Consent Form

I have read the information regarding this research and I have been informed about all aspects of the study and all questions I have asked have been answered to my satisfaction. I agree to participate in the activity, realising that I can withdraw from the exercise, if I wish, at any time.

I may also be invited as one of the five teachers who will take part in the second part of the study.

I also agree that the data gathered from this study might be published provided that my name, my school and my students are not identifiable.

Participant______________________________

Date:............

Benjamin, M. A______________________________
## APPENDIX G: CODING MANUAL

CODING MANUAL FOR SURVEY QUESTIONNAIRE.

<table>
<thead>
<tr>
<th>COLUMN</th>
<th>QUESTION</th>
<th>CODING</th>
</tr>
</thead>
<tbody>
<tr>
<td>SECTION 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A (Sn.)</td>
<td>-</td>
<td>Subject Number = 65</td>
</tr>
<tr>
<td>B (u_r)</td>
<td>1</td>
<td>Urban = 1; Rural = 2.</td>
</tr>
<tr>
<td>C(Age)</td>
<td>2</td>
<td>&lt; 20 = 1; 21-30 = 2; 31-40 = 3; 41-50 = 4; &lt; 50 = 5.</td>
</tr>
<tr>
<td>D (sex)</td>
<td>3</td>
<td>Male = 1; female = 2.</td>
</tr>
<tr>
<td>E (Qual)</td>
<td>4 (i)</td>
<td>Non-teaching qual = 0; NCE = 1; B.Sc + PGDE/B.Ed = 2; NCE + B.Ed/B.Sc = 3</td>
</tr>
<tr>
<td>F (P.qual)</td>
<td>(ii)</td>
<td>None = 0; M.Sc only = 1; M.Ed = 2; M.Sc + PGDE = 3</td>
</tr>
<tr>
<td>G (major)</td>
<td>5</td>
<td>Int.Sc + Biology/Chemistry/Physics/Maths. = 1; Biology; Biology + Agric/Chemistry = 2; Physics; Chemistry; Agric; Physics + Chemistry = 3</td>
</tr>
<tr>
<td>H (m.expr)</td>
<td>6</td>
<td>5 = 1; 6-10 = 2; 11-15 = 3; 16-20 = 4; &gt; 20 = 5.</td>
</tr>
<tr>
<td>I (subj)</td>
<td></td>
<td>Only Sc. = 1; Mostly Sc. = 2; Some sc. but mostly... = 3.</td>
</tr>
<tr>
<td>SECTION 2.</td>
<td>2.1 &amp; 2.2</td>
<td></td>
</tr>
<tr>
<td>J (explng)</td>
<td></td>
<td>Explaining/describing/Classifying = 1</td>
</tr>
<tr>
<td>K(demonst)</td>
<td></td>
<td>Demonstrating = 1</td>
</tr>
<tr>
<td>L(guid)</td>
<td></td>
<td>Guiding/Supervising = 1</td>
</tr>
<tr>
<td>M (discuss)</td>
<td></td>
<td>Discussing = 1</td>
</tr>
<tr>
<td>N (defin.)</td>
<td></td>
<td>Defining terms = 1</td>
</tr>
<tr>
<td>O(Charts)</td>
<td></td>
<td>Using charts/diagrams = 1</td>
</tr>
<tr>
<td>P(ask_ans)</td>
<td></td>
<td>Asking/answering questions = 1</td>
</tr>
<tr>
<td>Q (summar)</td>
<td></td>
<td>Summarising = 1</td>
</tr>
<tr>
<td>R (example)</td>
<td></td>
<td>Giving examples = 1</td>
</tr>
<tr>
<td>S (g_note)</td>
<td></td>
<td>Giving notes = 1</td>
</tr>
<tr>
<td>T(activit)</td>
<td></td>
<td>Giving class activities = 1</td>
</tr>
<tr>
<td>U(mod_spe)</td>
<td></td>
<td>Using models/objects/specimens = 1.</td>
</tr>
<tr>
<td>2.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V(listen)</td>
<td></td>
<td>Students Roles</td>
</tr>
<tr>
<td>W(ask_qn)</td>
<td></td>
<td>Listening = 1</td>
</tr>
<tr>
<td>X(ans_qn)</td>
<td></td>
<td>Asking questions = 1</td>
</tr>
<tr>
<td>Y(g.activi)</td>
<td></td>
<td>Answering questions = 1</td>
</tr>
<tr>
<td>Z(i.activi)</td>
<td></td>
<td>Performing group activities = 1</td>
</tr>
</tbody>
</table>
Performing individual activities = 1
Observing specimens/models = 1
Discussing = 1
Taking notes = 1

Effective = 1; ineffective = 2.

Reasons for being effective:
(a) Students respond to questions = 1
(b) Students contribute to discussion = 1
(c) They participate in demonstration = 1
(d) Students show interest in concept = 1
(e) They observe real objects = 1

Reason for ineffectiveness:
(a) Large class = 1
(b) Poor sitting arrangement = 1

Class size.
>30 = 1; 31-40 = 2; 41-50 = 3; 51-60 = 4; 61-70 = 5;
71-80 = 6; 81-90 = 7; 91-100 = 8.

Typical 40 minutes lesson.
(including zero time)
(a) Explaining
(b) Giving notes
© Supervising
(d) Whole class discussion
(e) Small group discussion
(f) Students reading text.

Typical 80 minutes practical lesson.
(including zero time)
(a) Teacher demonstration
(b) Students’ group work/activities
(c) Individual student’s activities
(d) Teacher explaining
BD(proced) 2.10 How often do you give experimental procedure/s to students?
   (a) All the time = 4
   (b) Most of the time = 3
   © Some time = 2
   (a) Never = 1.

BE(s_invest) 2.11 How often do students plan their own investigation?
   (a) All the time = 4
   (b) Most of the time = 3
   © Some time = 2
   (d) Never = 1

BF (facility) 2.12 How adequate are the facilities for teaching practical lessons?
   (a) Very good = 4
   (b) Adequate = 3
   © Very poor = 2
   (d) Not available at all = 1.

BG(demo) 2.13(a) Teaching is effective when the teacher does....?
   1. Demonstrates the concept he is teaching before the class = 1
   2. Explains the concept effectively = 1
   3. Ensures that students learn by doing activities = 1
   4. Has good knowledge of subject matter = 1
   5. Uses various teaching skills during his lesson = 1
   6. Encourages students to find out by themselves = 1
   7. Encourages students to ask/answer questions = 1
   8. Can arouse students’ interest in the concept. = 1
   9. Directs and takes adequate control of the class activities = 1
10. Gives enough exercises and examples in class = 1
11. Organises his/her lesson from simple to complex = 1
12. Uses real objects/specimens = 1
13. Engages the students in class discussion = 1
14. Gives notes to the students on each topic taught = 1
<table>
<thead>
<tr>
<th>BV(classmgt)</th>
<th>15. Supervises individual student’s work regularly =1</th>
</tr>
</thead>
<tbody>
<tr>
<td>BW(stilevel)</td>
<td>16. Effectively manages the classroom =1</td>
</tr>
<tr>
<td>BX(improvi)</td>
<td>17. Takes into account the developmental level of the students =1</td>
</tr>
<tr>
<td>BY(stlives)</td>
<td>18. Has the ability to improvise teaching materials where necessary =1</td>
</tr>
<tr>
<td>BZ(n_ahead)</td>
<td>19. Relates the concepts to students’ lives =1</td>
</tr>
<tr>
<td>CA(evaluatn)</td>
<td>20. Gives the topic out to students ahead of the lesson. =1</td>
</tr>
<tr>
<td>CC(instr_ma)</td>
<td>22. Allows students’ participation in the lesson.</td>
</tr>
<tr>
<td>CD (Pl_ahead)</td>
<td>23. Makes use of intructional aids=1</td>
</tr>
<tr>
<td></td>
<td>24. Plans well ahead of the lesson =1</td>
</tr>
</tbody>
</table>

2.13 (b)  

Teaching is effective when the students do…?

1. Listen attentively and follow instructions during the lesson =1
2. Are adequately engaged in class activities =1
3. Can apply previous knowledge to tackle new problems =1
4. Find out things on their own =1
5. Can adequately observe teacher’s demonstration =1
6. Ask and answer questions in class. =1
7. Keep good notes.
8. Do all assignments =1
9. Show interest in the study of science =1
10. Relate very well with their teacher. =1
11. Are keen to know more and to explore more =1
12. Contribute during class discussion.

Factors that limit teaching effectiveness

1. Limited teaching materials/resources.
2. Poor attitude of students towards science
3. Inadequate laboratory .
4. Lack of current science text books.
5. School does not allow students to be taken out of class to learn science.
6. Unconducive teaching/learning environment .
7. Lack of support from parents.
8. Inadequate motivation /incentives for science teachers.
9. Too large classes.
10. Insufficient number of qualified science teachers.
11. Insufficient time for each period.
12. Cultural beliefs of the community.
13. Lack of stable government educational policies.
14. Poor background of students in science.
15. Too much work load.
17. Inadequate number of periods.
18. Insufficient free-hand/freedom.

Purpose of assessing students.

1. To know if lesson objective is achieved.
2. To test students' ability/learning outcome.
3. To find out the problem areas in the scheme of work.
4. For their promotion to the next class.
5. To encourage students to study harder.
6. To give a feedback to their parents.
7. To evaluate oneself as the teacher.
8. To keep record of individual student's performance in the school.
9. To find out if students understand the concept being taught.
10. To determine students' scores.
11. To improve teaching.

Assessment methods

1. Terminal examinations.
2. Regular class exercises.
3. Periodic tests/continuous assessment.
4. Take-home assignments.
5. Projects.
6. Attendance in class.
7. Grading of practical notes.
8. Assessment of skills during practicals.

A quiet class is generally needed for effective learning.

(a) Strongly disagree = 1
(b) Disagree = 2
© Undecided = 3
(d) Agree = 4
| DD (tr_activ) | (e) Strongly agree =5  
|              | It is better when it is the teacher who decides what activities to be done.  
|              | (a) Strongly disagree =1  
|              | (b) Disagree =2  
|              | © Undecided =3  
|              | (d) Agree =4  
|              | (e) Strongly agree =5  
| DE(initiat). | Students will take more initiatives to learn when they are free to move round the class.  
|              | (a) Strongly disagree =1  
|              | (b) Disagree =2  
|              | © Undecided =3  
|              | (d) Agree =4  
|              | (e) Strongly agree =5  
| DF(assesmt) | Students should help establish criteria that will be used to assess them.  
|              | (a) Strongly disagree =1  
|              | (b) Disagree =2  
|              | © Undecided =3  
|              | (d) Agree =4  
|              | (e) Strongly agree =5  
| DG(r_lives) | How much students learn depends on the relevance of the lesson to their lives.  
|              | (a) Strongly disagree =1  
|              | (b) Disagree =2  
|              | © Undecided =3  
|              | (d) Agree =4  
|              | (o) Strongly agree =5  
| DH(ex_knw)  | An important factor affecting what a student learns is his/her existing knowledge and beliefs.  
|              | (a) Strongly disagree =1  
|              | (b) Disagree =2  
|              | © Undecided =3  
|              | (d) Agree =4  
|              | (e) Strongly agree =5  
| DI(sc_knw) | Scientific knowledge does not change.  
|              | (a) Strongly disagree =1  
|              | (b) Disagree =2  
|              | © Undecided =3  
|              | (d) Agree =4  
|              | (e) Strongly agree =5  
| DJ(sc_nat.) | Science is a collection of facts about nature.  
|              | (a) Strongly disagree =1  
|              | (b) Disagree =2  
|              | © Undecided =3  
|              | (d) Agree =4  
|              | (e) Strongly agree =5  
| DK(sc_inv)  |
Science is a way of investigating and developing understanding about the natural world.

(a) Strongly disagree =1
(b) Disagree =2
© Undecided =3
(d) Agree =4
(e) Strongly agree =5

Science theories are revised as new evidences are generated.

(a) Strongly disagree =1
(b) Disagree =2
© Undecided =3
(d) Agree =4
(e) Strongly agree =5

### SECTION 4.

**DM(cor_ans)**

To see if students know the correct answer.

- (A) Never =1
- (B) Sometimes =2
© Often =3
- (D) Very often =4

**DN(hwork)**

To see if they have done their homework.

- (A) Never =1
- (B) Sometimes =2
© Often =3
- (D) Very often =4

**DO(St_idea)**

To elicit the students' ideas or opinions.

- (A) Never =1
- (B) Sometimes =2
© Often =3
- (D) Very often =4

**DP(st_reas)**

To get the students to explain their reasoning.

- (A) Never =1
- (B) Sometimes =2
© Often =3
- (D) Very often =4

**DQ(st_expr)**

To make the students relate what they are learning to their own experience.

- (A) Never =1
- (B) Sometimes =2
© Often =3
- (D) Very often =4

### SECTION 5.

**DR(ent_knw)**

I believe that science curriculum should emphasise content knowledge.

- (A) Strongly disagree =1
- (D) Disagree =1
I believe that science curriculum should emphasise methods of inquiry in science.
(a) Strongly disagree = 1
(b) Disagree = 2
(c) Undecided = 3
(d) Agree = 4
(e) Strongly agree = 5

I believe that curriculum content should be based on social issues.
(a) Strongly disagree = 1
(b) Disagree = 2
© Undecided = 3
(d) Agree = 4
(e) Strongly agree = 5

I believe that science curriculum should be relevant to students' environment and lives.
(a) Strongly disagree = 1
(b) Disagree = 2
© Undecided = 3
(d) Agree = 4
(e) Strongly agree = 5

I believe that the content of the Lagos State Int. Science:
Is comprehensive.
(a) Strongly disagree = 1
(b) Disagree = 2
(c) Undecided = 3
(d) Agree = 4
(e) Strongly agree = 5

Is current.
(a) Strongly disagree = 1
(b) Disagree = 2
(c) Undecided = 3
(d) Agree = 4
©
(e) Strongly agree = 5.

Is relevant to students' needs.
(a) Strongly disagree = 1
(b) Disagree = 2
(c) Undecided = 3
(d) Agree = 4
©
(e) Strongly agree = 5.

Its objectives are achievable.
(a) Strongly disagree = 1
DZ (flexible)

(b) Disagree = 2
(c) Undecided = 3
(d) Agree = 4
(e) Strongly agree = 5

Is flexible enough to enable me use various teaching methods,

(a) Strongly disagree = 1
(b) Disagree = 2
(c) Undecided = 3
(d) Agree = 4
(e) Strongly agree = 5.

A. Benjamin
APPENDIX H: AN INTERVIVEW

INTERVIEW WITH TELLO (8/02/02)

Good morning Tello; you are welcome to this interview section or session. Please can you respond to these demographic questions? Your name, your age, your school and educational qualification.

My name is Tello, my school is Lagos State Model College, Ojo, I am 35 years old. I have B.Sc in Bio Chemistry and PGD in Education.

I have been teaching science for about 10 years now.

Today date is 8/02/2002; the time now is 9.25am. We will go into the structured interview, which we discussed about now. I am going to ask you a few questions relating to your experiences in this school and your classroom science teaching in particular.

Qn: What do you believe are the characteristics of effective teaching and learning of science?

Res: The characteristics of an effective teaching and learning in science is that... in a situation whereby in a class the teacher is giving the precise instruction, he is moving round to check whoever is lagging behind and he is also giving them whatever they desire to get out of the class. ...In such a situation the teacher's role is to give precise instruction...precise and correct information...I mean clear and detailed explanation of... in which he should move round his class to ensure that no one is being left behind.

Prompt: Please can you explain further?

Res: Because being effective at any particular time means that everyone...is doing the right thing in the classroom i.e. the teacher is giving out...and the students are ready to take...it is not a situation whereby some of the students are not ready to get what the teacher is giving to them in form of knowledge. The teacher can only be said to be effective when he/she and the students are both involved in the learning process...I mean adequate explanation...with examples and demonstration...the teacher should be able to prepare the mind of the students too, so that they can be ready and willing to
learn... in a situation like that it is effective in the sense that the two tiers which are involved in learning process; the teacher and learners are busy doing there work very well.

**Qn:** In such an effective science classroom, please let us be more specific on the roles the students will play?

**Res:** Students should ask and answer questions in class, participate fully in all class activities and be able to read ahead of lessons... For instance in a class where the teacher is demonstrating...say the concept of the physical changes... students are supposed to observe, ask questions on areas they do not understand while the teacher should be ready to give answers in precise forms...You see, because they know that I am very open...and I think they trust me...and because of my close relationship with them, their attitude...I mean many of them have changed over the years, they seem to have more interest in science now

**Qn:** Thank you very much. Mr Tello. Let us look at your students now; how do you think your students learn best?

**Res:** They learn best when the atmosphere is conducive i.e. they are ready...as students they should be ready to ask questions and the teacher should be ready to answer the questions because I have been with them for almost two years now... I started with them when they were in JSS1; I already know them, so when they are asking the wrong questions I know how to tailor them to the right answers so, I have studied them for sometime, ...as I said , they are sensitive...they are always watching you, especially when you are somehow close to them. I found that they learn best when you make the learning environment conducive by relating well with them...that is, when you make them feel important and...maybe, relaxed...especially when you do not ignore them...you encourage them to come up with ideas and questions and you do not caution them when they give wrong ideas... I know when they are ready for learning and at that time they are always coming up with questions because the topic are always given to them ahead of the class.
Qn. What you are saying is that they learn best when they ask questions? Can I say in a relaxed atmosphere too?

Yes.

Qn. To what extent do you believe your science teaching is effective?

Res: I believe my teaching has been effective because at the end of each lesson I always observe the expressions on the faces of my students. When I feel they are happy and satisfied it gives me innate pleasure that I have done something fine...Like on a few occasions when I got to their class and I got to know through their actions that they were not quite ready...or when I felt that they might not gain much from the lesson if I began to coerce them...instead what I do is that I change the plan by giving some story to lighten up...the stories are always related to the topic that I want to teach them. For instance when I was going to teach the nervous system...I gave a story of somebody stepping on a sharp nail...asking them how they would feel if they were the victim of such an accident...then a discussion on sensory nerves opened up...everyone was trying to contribute...Because I already understand how they behave because many of them may not really like to learn science... so I have to present it to them in a way...so as to try and get the best out of them.

Qn. Thank you very much Tello. What I would ask you again is a related question. What do you do very well in your classroom teaching?

Res: What I normally do very well is explanation, I tried as much as possible to explain every details of the subject contents to the hearing of the students and I do also try to get them own response as regards their questions and a times they may ask irrelevant questions...but I would make sure I convert that irrelevant question to be relevant because I know out of every irrelevance there is relevance aspect of it...so, those are the things I tried to do and I counsel them too to in order to know what they are in the school for.
Qn. Is there any aspect of your work that needs improving?

Res: Yes in the aspect of notes writing, I am not good at giving notes but I trust whatever I am giving to the student so that is why I always give them the topic ahead so that whatever I am now giving them will now serve as ways of assisting them so that they will understand. However in terms of giving notes I know I am very poor and even in writing notes.

Qn. Are there any other areas that requires improvement?

Res: Some other areas which I think I should improve upon is that the time allotment to explanation because of the fact that I am not very good in writing notes I now seize the opportunity to explain even more to cover that gap and in that attempt I may exceed normal duration of lessons. I think that is what I should get corrected.

Qn: What are your views regarding the nature of science. Lets talk about science itself now; what are your views regarding the nature of science?

Res: Science is the study of the natural world; things that exists in nature. These things are concrete...I guess it has to be made concrete or real as we teach it so that the students, whom we are teaching, should be able to get something out of it. This is because of the fact that it is the study of nature and in some cases it can appear to be abstract...so, I guess the more we concretize issues in science the better these students will get the best out of it.

Qn: How would you want the students...these ones you teach here to view science?

Res: I want my students to view science like I said earlier ---- because in science there is no two ways about it...it is the study of nature. They should always view it as something they can see and be able to explain some of those things. Naturally, for them to be able to do this it must be made concrete. ...That is the moon and that is the sky...they are parts of nature...both can be seen by the students; they can talk about them... but to be able to do so, we need to concretise them as we teach... and I would advise our curriculum planners... and the school to try and provide instructional materials that will help us present these things to our students in a way
they can easily understand and make sense of it, so that we can make science learning easier for the students.

*What you are saying, if I get you right, is that you try to make it real for them. Let us go to the students again.*

**Qn:** Why do you think science is taught to these students in school?

**Res:** I think science is taught to these students in the school so that they will be able to know the realities about the world... Knowing about the realities about the natural world will enable them to appreciate the work of nature... aesthetic feelings will be aroused in them... so that they can get to know scientific facts... for example, what happens to the food they eat in their body... how digestion takes place and knowledge of many things they make use of in their daily lives. We must not forget the fact that we also teach science to them in order to prepare them for science-based professions in future life.

**Qn:** I would ask you again could you please outline 3 most important factors, which inhibit your attainment of effective science teaching and learning in this school?

**Res:** One; inadequate science equipment; two; inadequate teaching aids

**Prompt:** Are you naming them in other of importance?

**Res:** Yes and lastly the lack of adequate textbooks for the students if you take the other way... because we don't have enough equipment, there some practical aspect of the subject that we are not able to try out in the laboratory. This is because, the student too did not have the right text book they will not be able to read something ahead and science you cannot do everything at the same time in the laboratory... it is not possible, there are some aspect of it you need to go and sleep over and you need to have the required texts to prepare... and there are some aspects that need practicals... so that when they see it they will find it easier to understand.

**Qn:** You have just mentioned 3 factors, which limit your attainment of effectiveness in your teaching; please can you suggest how these factors can be addressed?
Res: I think the government allocation into the educational funds should be increased, and by increasing it, they will now be able to provide and assist some scientific oriented authors to produce books at subsidized rates to the masses or to provide books for the students... this will make science teaching and learning easy... then they can as well allow some organized private sector to sponsor the production of science equipment which will now be made available to us. Inadequate manpower is also one of the problems because the teachers that are employed too have to be taken care of so that they can give their best to their students.

Qn: Let me take you back a little; did you say inadequate manpower is one of the problems or shortage of science teachers?

Res: Inadequate manpower is one of the problem, for instance, in my school I have handle mathematics for the last 3 years I handle further math's and at the same time integrated science... if there 's no problem of manpower that could not have happened. The turn out in our Universities now I don't know if you are conversant with it the statistics as of now, you find out we turn out more of Arts and Social science than scientist so... those things are now affecting most of us...that is the reason some people who did science as minors are being given physics for example to teach. Above all the most important thing is that the government should try and increase the allocation of fund for science teaching in the school system.

Qn: Let us come back to your own students; how do they prefer to learn?

Res: My students preferred to learn when the atmosphere is conducive...as I said, they are sensitive...they are always watching you, especially when you are somehow close to them. I found that they learn best when you make the learning environment conducive by relating well with them...that is, when you make them feel important and...maybe, relaxed...especially when you do not ignore them...you encourage them to come up with ideas and questions and you do not caution them when they give wrong ideas. They are happy when you illustrate whatever you are giving them or concretize them ..may be with charts or drawings on the board.
Qn: Are you saying the students are happy or happier when the teacher gives illustration and makes the concepts real?

Res: Yes, you are putting into practice the use of two of their sense organs for instance they see it... you are now showing it to their brain... they can visualize it, you have made it real to them and they will be able to remember the concept anytime...and that is what makes students happy and this will make your teaching easier and you will need to prepare less notes.

Qn: How do they behave in such a situation?

Res: Then they will appreciate what you are doing...you know we did a bit of psychology during our teacher training courses...and even in and out of the class my students are always happy with me...because whatever I am teaching them I try as much as I can to make it real and they always feel happy.

Qn: Why do you assess your students and how do you assess them?

Res: They are assessed in order to know how much knowledge they have acquired...their ability and most of the time because they have to be promoted to the next class ...as for me...I always assess the cognitive aspect of knowledge and skills...because I believe that the skill they acquire now will be useful sometime in the future; the subject content will also enable them use the skill better.

Being a scientist myself ...indeed I did my major in the pure science and then went to do the PGDE in education... I always assess the cognitive aspect of their knowledge and their skills...because I believe that the skills they acquire now are what they are going to use in the future. The subject content will also enable them to use the skill better...so, which is why I always assess their skill and their knowledge of the subject content.

Qn: What are the methods you use in assessing them?

Res: The methods that I use most of the time are: I grade students’ attendance in all my classes, their participation in the practical works, their continuous assessment /regular tests and also their examination which is the ultimate because they have to be promoted to the next class at the end of the school year. Concerning their skills, I group them and give them practical works or projects and I record the names of members of each
group...sometimes up to 13 groups...and I assess the presentation of their projects or group works...I give scores based on how best each group presents their work. Basically because it's practical work they always score above average marks. 

In the examinations I always give them written questions, which they will be required to answer at a given time frame.

**Thank you very much Tello, I look forward to seeing you again when you come back from this break. We will meet again in your classroom for the observation sessions.**
APPENDIX I

Time-table for School Visitations

<table>
<thead>
<tr>
<th>DATE</th>
<th>VISITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>4/9/01</td>
<td>Submitted letters of request to Ojo and Amuwo LEDs.</td>
</tr>
<tr>
<td>5/9/01</td>
<td>Collected the Letter of Approval from Amuwo LED.</td>
</tr>
<tr>
<td>12/9/01</td>
<td>Schools in Ojo school complex: Ojo secondary school; Ojo High School, and Model College.</td>
</tr>
<tr>
<td>13/9/01</td>
<td>Amuwo Secondary school &amp; Festac college.</td>
</tr>
<tr>
<td>14/9/01</td>
<td>Schools in Alimosho (Used for the Pilot Study, 10/9/01-3/10/01)</td>
</tr>
<tr>
<td>10/9/01-3/10/01</td>
<td>All secondary schools in Ojo LED</td>
</tr>
<tr>
<td>10/10/01</td>
<td>Administered the Survey Questionnaire</td>
</tr>
<tr>
<td>17/10/01</td>
<td>—</td>
</tr>
<tr>
<td>22/10/01</td>
<td>Collected the Survey Questionnaire</td>
</tr>
<tr>
<td>15/10/01</td>
<td>Collected the letter of approval from Ojo LED.</td>
</tr>
<tr>
<td>8/10/02</td>
<td>Case Studies Started.</td>
</tr>
<tr>
<td></td>
<td>Visit Amuwo Secondary School, Ojo High School, Model College, and Awori College.</td>
</tr>
<tr>
<td>8/2/02</td>
<td>Interview with Tello.</td>
</tr>
<tr>
<td>28/2/02</td>
<td>Lesson observation with Tello.</td>
</tr>
<tr>
<td>4/3/02</td>
<td>Lesson observation with Tello.</td>
</tr>
<tr>
<td>8/3/02</td>
<td>Interview with Angy.</td>
</tr>
<tr>
<td>11/3/02</td>
<td>Lesson observation with Angy.</td>
</tr>
<tr>
<td>19/3/02</td>
<td>Lesson observation with Angy.</td>
</tr>
<tr>
<td>8/4/02</td>
<td>Lesson observation with Angy.</td>
</tr>
<tr>
<td>18/4/02</td>
<td>Lesson Observation with Tello.</td>
</tr>
<tr>
<td>22/4/02</td>
<td>Lesson observation with Angy.</td>
</tr>
<tr>
<td>25/4/02</td>
<td>Interview with Kaudry.</td>
</tr>
<tr>
<td>28/4/02</td>
<td>Lesson observation with Tello (Practical).</td>
</tr>
<tr>
<td>10/5/02</td>
<td>Lesson observation with Angy (Practical).</td>
</tr>
<tr>
<td>15/5/02</td>
<td>Lesson observation with Kaudry</td>
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<td>20/5/02</td>
<td>Lesson observation with Kaudry</td>
</tr>
<tr>
<td>28/5/02</td>
<td>Lesson observation with Angy.</td>
</tr>
<tr>
<td>3/6/02</td>
<td>Lesson observation with Kaudry (Practical)</td>
</tr>
<tr>
<td>12/6/02</td>
<td>Lesson observation with Kaudry.</td>
</tr>
<tr>
<td>19/6/02</td>
<td>Lesson observation with Kaudry.</td>
</tr>
</tbody>
</table>

END OF DATA COLLECTION