7th INAUGURAL LECTURE

AND THE BARRIERS TO MEANINGFUL LEARNING OF SCIENCE CAME TUMBLING DOWN

by

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Preamble

It is a delight to present today, the 7th in the series of Inaugural Lectures of the University. It is to the Almighty God that the glory goes for the stories of our lives, mine far from being an exception.

On a number of occasions, immigration officials at the airport, on flipping through my passport, would say: "Occupation, uh! teaching. Oh! so you are a teacher?" I normally reply with a proud "Yes". "Oh! so you are even a Professor!", such officials continue. "What about it?", I normally retort. "You are lucky you are still young, no grey hairs. Why don't you look for better things to do, since age is still on your side?" "Don't be deceived by not seeing my grey hairs", I typically reply. "The trick is that anytime I am going out, I leave my grey hairs at home. But more importantly, I think our professors should be encouraged to stay rather than stray. Especially these days when the level of trust in the system leads some university students to say "give us the certificate first and we will come for the knowledge later".

The symptoms of the ailing state of science education in Nigeria will be given a brief description during the course of this lecture. Let us take a sniff in this preamble. In 1990, the results of the Second International Science Study which compared achievement of primary and secondary school students in science were officially released. Nigeria came a shameful last in primary science and second to the last in secondary science. Japan came first in both categories. A few weeks ago, the results of the Third International Science Study were released. Nigeria did not participate in the study. The results which showed Singapore coming first and South Africa coming last bring to the fore the low profile nature of science teaching and learning in Africa.

Introduction

Life began on earth for us humans about four million years ago. The history books of science tell us so. We are also told by the chapter on evolution in such books that the cradle of human civilisation is Africa. Science, a subject that is concerned with the exploration of the natural world began when early man took to wandering, arts and crafts to support life. Thus, we can boastfully say that science as a process, began in Africa. Aside from the fact that the remains of the earliest humans have been found in Africa, evidence of what can be called ancient African science also exists. Some of the well-known contributions of ancient African science include one of the first intensive agricultural schemes; metallurgy, including the mining and smelting of copper, practised in Africa as far back as 4000 B.C.; and the system of hieroglyphic writing and the use of papyrus. The science of architecture also reached new heights with the pyramids. They were amazing accomplishments both in terms of construction and the mathematical and astronomical knowledge necessary to build and situate them.

Between 3000 and 2500 B.C., a calendar and numeration system were developed and a carefully defined medical system was established under the guidance of Imhotep, an African physician and architect. The Egyptians were responsible for many medical innovations. In addition to developing an elaborate herbal tradition and many methods of clinical therapy, they also devised a code of medical ethics. In Nigeria,...

During the Middle Ages, while Europe was experiencing a "dark" era and few scientific ideas were being presented, science and the pursuit of knowledge were not dormant. Incredible amounts of scientific knowledge and data were being gleaned, nurtured, expanded and stored in the African continent, and some of this information would later stimulate Europe to its "Renaissance." In the seventeenth century Isaac Newton said: *"If I have seen further than most men, it is because I stood on the shoulders of giants."* As Newton well knew, not all of those giants were Europeans! Africa also featured scientific giants.

In spite of this apparent early lead, Africa remains, today, in the back seat in science and technology development. Why this is so and how the slumbering giant in the sun could be awakened are the over-arching issues that this lecture would address.

A distinctive feature of the present millennium of human history has undoubtedly been the birth of modern science and its subsequent exponential growth (Menon, 1995). A few hundred years ago, in Europe, the Scientific and Industrial Revolutions occurred and took root. Since then, the development of science has been gathering momentum but has flourished in only certain regions - chiefly Europe, North America and Japan.

The last century of this millennium has been characterised by an explosive growth of information, knowledge and understanding gained through scientific research. As a result of the technological application of this knowledge we have witnessed many ages occurring in parallel. Earlier periods of human history such as the Stone, Copper, Iron and Bronze Ages spanned prolonged periods of time. By contrast, the 20th century has seen the Atomic Age, the Space Age, the Age of Electronics and Informatics, the Age of New Biology, the Age of New Materials and the Age of Understanding the Organisation of the Universe.

During the last three decades as Menon (1995) further notes, the scale of scientific advancement has increased almost out of all recognition. This is evident whether the scientific enterprise is measured in terms of the number of active research workers, the expenditure on science, the number of research publications or the extent of production based on science and technology.

The recognition that science is important for development underscores the need for urgent intervention. Clearly, the minimum needs of human society, however populous, would have to be met in terms of food, shelter, clothing, water, energy, employment, basic education and health care. Without science and its synergistically-related discipline, technology, development in those sectors is nowhere.

How long shall we remain the footstool of the developed world through the neglect of science and technology? This is an important question that should agitate our minds in the twilight years of the 20th Century.

Another issue that would need to be taken along in this consideration is illiteracy. It has been reported by UNESCO that three-quarters of the world's illiterates live in only ten countries: India, China, Pakistan, Bangladesh, Nigeria, Indonesia, Brazil, Egypt, the Islamic Republic of Iran and Sudan (see Figure 1).

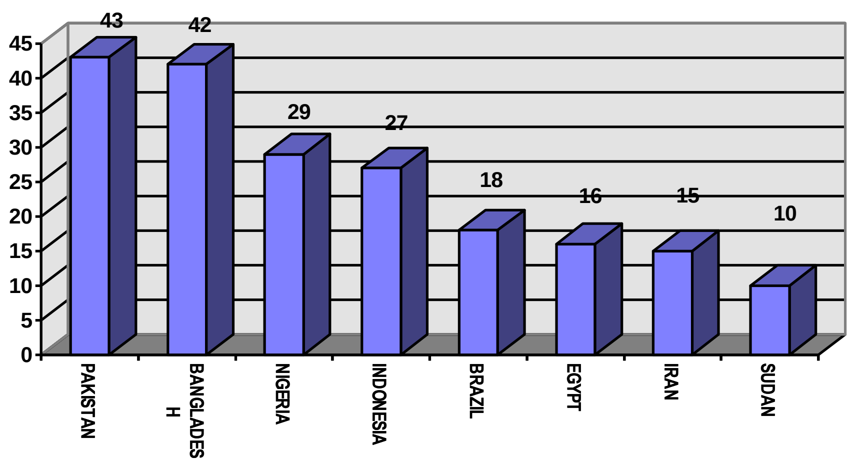

Fig. 1 Countries with highest number of illiterate adults (1990)
Note: India=281; China=224

What do these countries have in common? They share a number of challenges due to their physical size, and huge populations, and vast rural and remote areas. Many have considerable cultural and linguistic diversity. But developments in science and technology, coupled with these countries' inherent economic potential, present dramatic opportunities to meet the challenges of illiteracy.

The situation is compounded in Nigeria with the low level of investment in scientific and engineering research and experimental development. Table 1 shows that in 1995, Nigeria spent only 0.1% of the GNP on scientific and engineering research, easily one of the lowest in Africa and in the world.

Table 1: EXPENDITURE FOR SCIENTIFIC AND ENGINEERING RESEARCH AND EXPERIMENTAL DEVELOPMENT

COUNTRY	**AS % OF GNP**
AFRICA	
BENIN	**0.7**
EGYPT	**0.2**
MAURITIUS	**0.3**
NIGERIA	**0.1**
NORTH AMERICA	
CANADA	**1.4**
CUBA	**0.8**
ST. LUCIA	**2.9**
USA	**2.9**
SOUTH AMERICA	
ARGENTINA	**0.4**
BRAZIL	**0.4**
CHILE	**0.5**
VENEZUELA	**0.3**
ASIA	
INDIA	**0.9**
ISRAEL	**3.1**
JAPAN	**2.8**
SINGAPORE	**0.9**
EUROPE	
FRANCE	**2.3**
GERMANY	**4.3**
NORTHERLANDS	**2.2**
U. K.	**2.3**

Source: UNESCO 1995 World Science Report

In this lecture, the concept of meaningful learning of science will be examined and evidence provided that meaningful learning in science classrooms in Nigeria is hindered. This will be followed by a review of factors that impede science learning. The next section of the lecture provides summaries of our studies reporting how the barriers to the meaningful learning of science have been successfully hacked down. A 10-point agenda for change is finally proposed as a pathway for improving the profile of science and technology education in Nigeria.

Meaningful Learning in Science

In a learning setting, our intention as teachers is to move students from their entry point A to a higher point B where we expect the learning of the concept to have taken place. Between these two points of input and output is the process of instruction which leads to learning.

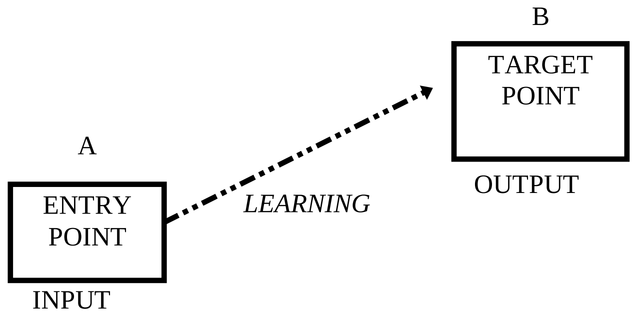

Fig. 3: Input-Output Model of Learning

How we learn has been a subject of intense research. This has led to the emergence of several learning theories and schools of thought. The "old brigade" schools include the behaviourists and the gestalt while theorists like Piaget and Bruner have stayed afloat in a sea of clashing empirical data. Within the last ten years, the constructivist's school of thought has emerged and is poised to be the dominant perspective in forthcoming years.

For the purpose of this lecture, I will fall back on the information processing model of learning that appears agreeable to many of the theorists and schools of thought. In a learning setting e.g. classroom, laboratory, church, mosque, while watching television or listening to the radio, or when scolded by an irate husband or wife, sensory data in the form of sound, vision, smell, taste and touch are received by the sense organs. These bits of sensory input, are encoded and finally passed to the brain where three things could happen. The encoded information may be (1) retained in the working memory; (2) later passed on to the Short-Term Memory (STM) store and (3) passed to the Long-Term Memory (LTM) store if there are repeats or rehearsals of the information.

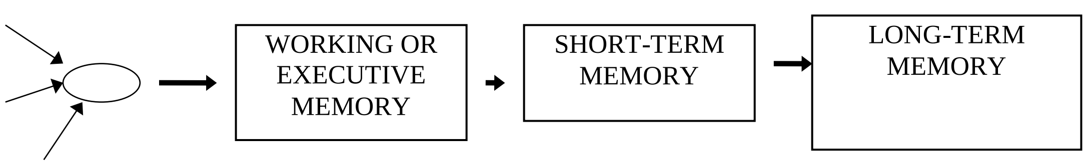

Fig. 2 Information-Processing Model

The platforms, if you like, shelves for storing the information in the STM or LTM are called schemata (singular = schema). The entire storage area, mainly in the grey matter region of the brain (cerebrum) is the cognitive structure.

Learning takes place when the information is stored either in STM or LTM. Information stored in STM lasts for only a few hours. If this information is not reinforced through rehearsal or repetition, it fades out of memory. For example, if a friend you met on the street tells you his telephone number is 09-2975823, the prediction is that if you met the friend about two hours later, you are likely to say "Please, could you remind me of your telephone number again?" STM has played a trick on you here!

Meaningful learning can best be described by contrasting it with its obverse - rote learning. To bring this contrast to sharp focus, let us work through by way of an example. Take a Primary 3 pupil who is able to flawlessly recite the multiplication table from 2 to 5.

Teacher: Tunde, what is 3 times 2?
Tunde: (a pause) Six.
Teacher: What about 3 times 9?
Tunde: (a long pause during which Tunde is muttering: 3 X1 =3; 3X2=6; 3X3=9... 3X8=24; 3X9=). The answer is 27.
Teacher: Good. Now Tunde, if a bus can carry nine people, how many of such buses will be required to carry 27 people?
Tunde: I am sorry Sir; I don't know. We have not done division in our class.

Plausible reasons exist for believing that rotely and meaningfully-learned materials are organised quite differently in cognitive structure and hence conform to quite different principles of learning and forgetting (Abimbola, 1988). First, meaningfully learned materials have been related to existing concepts in cognitive structure in ways making possible the understanding of various kinds of significant (e.g. derivative, correlative, qualifying) relationships. Most new ideational materials that students encounter in a school setting are relatable to a previously learned background of meaningful ideas and information. Rotely-learned materials, on the other hand, are discrete and relatively isolated entities which are only relatable to the cognitive structure in an arbitrary, verbatim fashion. Secondly, because they are not anchored to existing ideational systems, rotely-learned materials (unless greatly overlearned or endowed with unusual vividness) are much more vulnerable to forgetting, that is, have a much shorter retention span.

These differences imply that rotely-learned materials are essentially isolated from cognitive structure and hence are prone to interferences of various kinds (e.g. the interfering effects of similar learning materials learned immediately before or after the learning task.

Meaningful learning occurs when the student has been able to internalise information in the long-term memory store. The student who has meaningfully learned a concept is able to easily recall the information and apply the knowledge of the concept in solving novel problems. Take two students who have been taught electric circuits in the physics class. One of the students is able to redraw the electric circuit but not able to fix an electrical problem arising from a break in an electric circuit e.g. a non-functioning iron. The other is able to identify the problem of the faulty iron as a break in circuit and correct the problem. Student B could be said to have meaningfully learned the concept of electrical circuits.

Many teachers want their students to be homogeneous in thinking, even if they cannot be homogeneous in their appearance. Many teachers also bemoan the fact that students come to class unprepared to learn. Unfortunately, the students' worlds will not change overnight. Students will continue to come to school scared, hungry, and with emotional and behavioural problems, and teachers will continue to see students in different stages of readiness to learn a science concept.

BARRIERS TO MEANINGFUL LEARNING OF SCIENCE

Professor: Principal, why are you bringing these kind of students to us in the university?
Principal: Thank you. But why are you also bringing these kind of graduates to me in my school?

This conversation underscores the extent of the depreciating quality of our educational system and that the blame can be laid at several doorsteps. The home is blameworthy, the primary school is blameworthy, so also secondary and the higher institutions. In this section, we shall examine those factors which stand as barriers to meaningful learning of science

The Subject as a Barrier

It is a commonly held view among students that science is difficult to learn. This point of view is reflected when students are to make choices. Fewer students elect to study science subjects when compared with the arts. It is also a widely received view that it is easier for a science graduate later to pick up expertise in a non-science subject than vice versa. A humanities undergraduate straying into a final-year physics or chemistry lecture would be very unlikely to understand much of what is going on, yet many science undergraduates could wander into a corresponding history lecture and would at least be able to follow some of the gist of what was being said. Both the sciences and the arts may be equally 'hard' to do well, but science is found by students to be typically harder.

The difficulty lies in the 'distance' between the language of science and the mother tongue or if you like, the vernacular language. Compared to disciplines like history and literature, the language of science is distanced from vernacular language. Science involves logical chains of argument, couched in abstract language. In other subjects, where language and ideas remain closer to the vernacular, learners can draw on lay understanding to make sense of the discourse of the subject. The greater 'distance' of science discourse from everyday discourse makes this much more difficult. If, in addition, this abstract language is written in a symbolic form - mathematics - the difficulty becomes greater still.

Miller (1991) gives more insight by describing intrinsic and extrinsic reasons. Intrinsic reasons are the consequence of certain unavoidable characteristics of science and/or of learners; while extrinsic reasons are the consequence of decisions by science teachers and educators, which have the result of making science harder to learn than it actually needs to be.

There is, for instance, a marked reluctance on the part of many science educators to acknowledge that science is a consensually accepted body of knowledge, and a tendency instead of portray science primarily as an algorithm for obtaining knowledge of the natural world. Again contemporary philosophy of science has drawn attention forcefully to this deep tension within science between openness and scepticism on the one hand, and dogmatism on the other. This too is most commonly associated with the work of Kuhn but is also implicit in the writings of Popper. Science has an ethos and an associated rhetoric of openness to empirical findings and ultimate scepticism about current theoretical positions; all claims are open to testing by anyone who wishes, and no theory is claimed to be the final say on the matter. On the other hand, science has the most consensually agreed body of contents and practices of any developed discipline.

Because much of science is well established and consensually agreed, it is natural that the teacher will want to lead her or his class efficiently to the accepted understanding of the area they are working on. A consequence is that science can come to look like a simple description of the world - a reading of the book of nature - rather than the creative business of 'making sense' (Millar, 1991). In part this arises because the time and facilities to explore fully the evidence for most important scientific ideas are simply not available. As a result, classroom treatments often distort the nature of scientific evidence, by requiring that the learner accept the conclusion without access to adequate evidence for it. This makes science appear as a large collection of relatively 'useless' facts to be learnt. It also obscures from learners the overall purpose of science - a search for persuasive explanations about the nature and behaviour of the natural world.

The Learner as a Barrier

Readiness, motivation, cognitive preference orientation and general attitude to work are some attributes of the learner that pose barriers to meaningful learning of science. Bayelo (1987) Oladimeji (1989), Ajayalemi (1988), Bomide (1984) and Ajeyalemi (1990) have provided evidence that many Nigerian children at the primary and secondary levels are not cognitively ready for the type of science that teachers present. It has been established by these researchers and others, that teachers are presenting formal-operational concepts in science to students who are predominantly concrete operators. This is what Onwu (1992) described as cognitive mismatch rather than capacity deficit in explaining students' underachievement in science. This Piagetian position, is taken to contrasts with the Ausubelian position that any subject matter can be taught to any child in an intellectually honest way if given enough time and within a conducive learning environment. Without engaging in the discourse conflict between Ausubel and Piagetian on this issue, studies conducted in Nigeria point to the position that many students are not mature in their cognitive processing abilities to be able to effectively learn some science concepts.

On the issue of motivation, data have been provided e.g. by .... that the motivation level of many Nigerian students is low. With motivation level clearly a factor in meaningful learning, this low level of motivation could be seen to be a barrier to meaningful learning of science by Nigerian students. Closely tied with this is the widely reported poor attitude of students to work. Ask many science teachers and they will tell you how lazy their students are. Cases of refusal to do assignments and come to class are aplenty. Absenteeism, truancy are common practices especially in our urban areas which are clearly not disposing to serious academic work.

The Learning Environment as a Barrier

In a study conducted in 1989, we compared the preferred and actual science laboratory environments in Australia, USA, Israel and Nigeria. The preferred environment is a description of how students want their laboratories to be. The actual environment is the description of how the science laboratory is (at the time of the study). On all our measures, the Nigerian sample showed the greatest gap between the preferred and actual.
The actual science laboratories as I mentioned earlier are far from equipped for meaningful science teaching and learning. Even the classrooms are poorly equipped. Over populated classrooms are common place. The shocked-up classroom settings - no roof, and scanty furniture in many cases, are far from enabling in promoting meaningful learning.

Culture as a Barrier

Our studies have shown a number of factors that enhance science learning and some that are hindrances. Cultural barriers which we identified in our studies (e.g. Jegede and Okebukola, 1988, 1989 and 1990) are superstitious and taboos, authoritarianism, and societal expectations of affluence. These factors have emerged over the years to impede the access, participation and performance of students, especially girls in science.

The Science Teacher as a Barrier

The science teacher constitutes, in a number of ways, a barrier to the meaningful learning of science. The hindrance is not deliberate since the teacher is employed to facilitate learning. These hindrances are manifested in the poor preparation of science teachers, low level of motivation and high level of stress in the work environment, all adding up to poor instructional delivery.

Table 1: Mean Scores and Rank Order of Stress Factors

Students' Characteristics

S/No.	Prediction	Mean	Rank Order
1.	Poor attitude of students to science lessons	1.391	6
2.	Unruly and disruptive behaviour of students	1.218	7
3.	Breakage of/damage to expensive lab equipment	1.192	20
4.	Poor performance in science examinations	1.187	22
5.	Many science students do not behave like young scientists	1.180	23
6.	Failure of students to do assignments	1.196	19
7.	Students who look blank in science classes	1.200	17
8.	Students not coming to class with necessary materials	1.171	24

Teachers' Characteristics

S/No.	Prediction	Mean	Rank Order
9.	Having to teach a science subject one is not trained for	1.429	4
10.	Having to cope with the demands of new curricula	1.401	5
11.	Fear of getting injured as a result of lab accidents	1.192	20
12.	Lack of interest in teaching as a profession	1.163	25
13.	Difficulty in completing the syllabus in the time available	1.506	3
14.	Having to cope with teaching difficult topics	1.583	2
15.	Having to teach students who are not motivated to learn Science	1.286	9
16.	Not enough time to complete lesson preparation and marking	1.151	26
17.	Having to cover lessons for absent teachers	1.143	28
18.	Insufficient time to deal with private matters	1.151	26

School Environment

S/No.	Prediction	Mean	Rank Order
19.	Difficulty in obtaining science teaching equipment	1.621	1
20.	Lack/inadequacy of laboratory support personnel	1.213	10
21.	No colleagues to consult on science teaching problems	1.126	29
22.	Large science classes	1.318	7
23.	Noise and other disturbances from neighbouring classrooms	1.105	30
24.	Lack of classroom space for group work	1.068	31
25.	Non-supportive role of other teachers towards science teaching	1.053	32
26.	School environment not having location for field work	0.002	33
27.	Pace of the school day is too fast	0.801	40

Administrative Procedure

S/No.	Prediction	Mean	Rank Order
28.	Inadequate disciplinary policy of the school	0.966	34
29.	Having to comply with decisions made without consulting teachers	0.929	35
30.	Having to cope with non-teaching delegated duties	0.801	36
31.	Principal's reluctance to reprimand misbehaving students	1.200	17
32.	Assignment to classes not preferred	1.201	15
33.	Principal's reluctance to deal with difficult parents	0.843	37
34.	Unfavourable school time-table	1.201	15
35.	Having to cope with policies that are not supportive of science teaching	1.206	11

Conditions of Service

S/No.	Prediction	Mean	Rank Order
36.	Lack of opportunities for professional improvement	1.206	11
37.	Unattractive salary	0.821	38
38.	Delay in promotion	0.806	39
39.	Lack of opportunity to experiment with new ideas	1.206	11
40.	Lack of incentives and rewards for hard work	1.206	11

In STAN’s Position Paper No. 4, the following factors were identified as responsible for students’ underachievement in science.

Government-related factors

- Lip service paid to STM education as evidenced by gross underfunding.
- Inadequacy of reward for excellence in science teaching and learning
(Better reward system is applied to footballers and musicians).

Examination Body-related factors

- Overloaded examination syllabus
- Unfavourable mode of setting questions schemes

Teacher-related factors

- Low morale of STM teachers as a consequence of the low ranking of the teaching profession.
- Poor preparation of STM teachers.
- Lack of motivation of many STM teachers.
- Inadequate knowledge of subject matter.
- Lack of skills/competence required for teaching.
- Lack of skills of improvisation.
- Shortage of qualified STM teachers.

Student-related factors

- Poor attitude of students to work.
- Apprehension that STM are naturally difficult subjects to learn.
- Difficulty with learning symbols associated with STM.
- Difficulty with calculations involved in STM learning.
- Difficulty with learning the language of STM.

School-related factors

- Overcrowded classrooms.
- Overloaded examination syllabus.
- Lack/Inadequacy of lab and workshop facilities.
- Allocation of too many periods to STM teachers.
- Poorly equipped school libraries.
- Shortage of qualified support personnel such as lab and workshop assistants.
- Lack of vital instructional materials such as textbooks, teacher's guides and audio-visual.

Home-related factors

- Negative influence of some cultural beliefs e.g. superstitions and practices e.g., authoritarianism on learning of concepts in STM.
- Imposition by parents of science subjects on children in spite of poor aptitude for STM.
- Non-monitoring at home of students' progress in science.
- Lack of provision in many homes for the educational needs of students in STM.
- Craze for careers in business and banking rather than for science and technology related courses.

EVIDENCE OF BARRIERS IN ACTION

That many of our students have not attained meaningful learning of science is seen in several ways one of which is in their performance profiles especially in public examinations. For instance between 1981 and 1994, the ranges of percentage passes in science subjects are:

Agriculture Science	15.28 - 49.27
Biology	6.01 - 25.55
Chemistry	4.13 - 39.15
Mathematics	6.26 - 21.69
Physics	9.50 - 25.85

Table 3 summarises the results of students in SSCE Science

Table 3: Summary of performance of candidates in SSCE (Science subjects)

BIOLOGY

YEAR	ENTRY	TOTAL GRADES 1-6	TOTAL GRADES 7-8	TOTAL FAIL	% IN GRADES 1-6
1981	160941	21693	267044	112544	13.48
1982	237761	14454	26519	196808	60.08
1983	276990	24742	32917	219331	8.93
1984	299834	31707	60018	207308	10.60
1985	350476	41111	71221	237950	11.73
1986	392075	63389	86558	86558	16.17
1987	310501	34740	74642	201119	11.19
1988	345687	32520	81867	231300	9.41
1989	87710	10379	19552	57779	11.83
1990	190386	29942	58674	101770	15.73
1991	285690	72988	82270	130432	25.55

CHEMISTRY

YEAR	**ENTRY**	**TOTAL GRADES 1-6**	**TOTAL GRADES 7-8**	**TOTAL FAIL**	**% IN GRADES 1-6**
1981	85992	18705	23434	43853	21.75
1982	10782	18848	31533	67445	17.48
1983	113473	13966	23408	76099	12.31
1984	112729	28779	76016	66834	25.53
1985	114380	22630	21857	69893	19.78
1986	134154	52523	70984	44622	39.15
1987	120765	32676	53952	46677	27.06
1988	142699	42182	48565	51952	29.56
1989	35702	3862	9522	22321	10.82
1990	80059	3307	16657	60095	4.13
1991	116526	12117	23585	80824	10.40

PHYSICS

YEAR	ENTRY	TOTAL GRADES 1-6	TOTAL GRADES 7-8	TOTAL FAIL	% IN GRADES 1-6
1981	36469	8973	8499	18997	24.60
1982	49587	10106	12059	27422	20.38
1983	60531	8819	12343	39369	14.57
1984	62668	14690	14891	33087	23.44
1985	63062	16303	13880	32879	25.85
1986	79746	19790	19983	39973	24.82
1987	76656	18922	28428	40564	24.68
1988	94963	29577	22129	48257	31.15
1989	28524	2710	7688	18126	9.50
1990	63161	12741	20323	30097	20.17
1991	96742	17037	28601	51104	17.61

The poor performance of students in science in examinations that are conducted by the Joint Admissions and Matriculation Board, the under-representation of girls in science and the increasing incidence of examination malpractice are other indicators of barriers in action.

BREAKING BARRIERS

The Attack Plan

Composite plans for dealing the death blow on the menace of poor quality science education in Nigeria have been the subject of Annual Conferences and National Workshops of the Science Teachers Association of Nigeria (STAN) especially since 1971. The *Journal of the Science Teachers Association of Nigeria* and the *Proceedings of STAN's Annual Conferences* are replete with position papers on the subject. Also on target is STAN Position Paper No. 4 on "*Raising the Standards of Performance in Science in School and Public Examinations"* which was published in 1992.

Between 1979 and 1989, we examined the potency of an attack plan and convinced of its merit, decided on a frontal assault on the identified barriers to the meaningful learning of science. A couple of colleagues, crack researchers and science educators all, signed on to collaborate in the implementation of the plan. We went in for the kill using concept mapping as our scud missile, cooperative learning as our smart bomb and analogies as our surface-to-air missile. We were able to pull together seven potentially deadly weapons in our arsenal. The theatre of war had been experimental sites at the secondary and university levels. We won the battle on all fronts, hacking down the barriers to meaningful learning of science. Our methods have been replicated in Nigeria and in other parts of the world and found to be what the Yorubas call *"ogun amu bi idan"* (potent medicine) for facilitating meaningful learning. While no claim of patent to these methodologies is being made, the use of the methods in modulated combinations is unique to our studies. We hold the patent for this and would want to make the modest claim that no reported study of substance in the top three journals in science education in the world on strategies for promoting meaningful learning of science would go past the eye of the Editor without a citation of Okebukola or Okebukola & Jegede. We are also delighted to note that the article "Influence of preferred learning styles on cooperative learning in science, published by Okebukola, won the outstanding paper award in 1985.

After the foregoing trumpet blowing, let us glean snapshots from some of the studies which used strategies for hacking down the barriers to meaningful learning of science. Perhaps an insight into our experimental plan is a good starting point.

Our studies have been mainly quasi-experimental. An experiment as viewed by the legendary Campbell & Stanley (1967) is the primary means by which we are able to establish cause-effect relationships between certain events in the environment and the occurrence of particular forms of behaviour. The basic notion is simple: At least two groups of subjects (persons) are treated exactly alike in all ways except one - the differential treatment. Any differences observed in the behaviour of the two groups of subjects is then attributed to, or said to be caused by, the difference in the specific treatment condition. If the subjects of the study are randomly assigned to experimental and control conditions, you have a "pure" experiment. If however, random assignment is impossible, a quasi-experiment results. Since our studies took place in real classroom settings where random assignment to groups was difficult to achieve in order not to disturb school routine, we settled for quasi-experimental models as depicted in the diagram below.

$\mathbf{E_1}$	$\mathbf{O_1}$	$\mathbf{X_a}$	$\mathbf{O_2}$
E2	$\mathbf{O_3}$	$\mathbf{X_b}$	$\mathbf{X_4}$
C	$\mathbf{O_5}$		$\mathbf{O_6}$

where:

E_1 and E_2 are experimental groups 1 and 2
C represents the control group
O_1, O_3, and O_5 are pretests
X_a and X_b are treatments
O_2, O_4 and O_6 are posttests

We took care of the initial differences in the entry performance of our subjects to the quasi-experimental settings by subjecting the data to the analysis of covariance procedure where uni-output variables were concerned. In situations where mixed output variables were of interest, we settled for the multivariate analysis of covariance. The covariates were usually pretest scores. ANCOVA and MANCOVA are highly-robust statistical tools to the extent that they are able to withstand violations to some of the assumptions of normality, homogeneity of variance and random assignment.

The flow of the studies is normally of the type:

1. Assign groups to experimental and control conditions
2. Pretest on the measures of interest
3. Apply treatment
4. Posttest on the measures of interest
5. Give retention test after weeks of giving the posttest.

The Attack

We fired the first shot at the barriers to meaningful learning of science using the cooperative-learning strategy as our high-velocity bullet. An earlier survey (Okebukola, 1978) and a scan of the literature showed that the laboratories especially of our public schools are ill-equipped and do not afford students opportunities for individual practical work. What do you have in the biology laboratory? A few weather-beaten microscopes, a litter of awful smelling preserved specimens, a few hand lenses, to be used by 200+ senior secondary students, many of whom have been compelled by certificate requirements to do biology. Walk into the Chemistry laboratory. Few glassware including a handful of burettes and near-empty reagent bottles are what you find. Physics? Worse still. At the primary level, the nature corner with a few odds and ends make up the laboratory. At the university level, many obsolete equipment adorn the laboratories. In these settings, meaningful learning takes a dive out of the window.

The idea behind the cooperative-learning strategy is to disallow meaningful learning from jumping out of the window in spite of the constraints of facilities. Instead of the science teacher refusing to do practical work because equipment cannot go round his/her army of students, the few items of equipment can be used optimally by groups (if you like, platoons) of students on cooperative-learning basis. Common sense? Yes! But where is the empirical proof of efficacy? We provided this through a series of experiments which we started in 1980. The first in the series of studies compared the performance in practical skills, cognitive achievement and attitude towards biology of 1,047 students in three groups - cooperative, competitive and individualistic. Our results were mixed, some of which ran "against the run of play" in the science education literature but which finally earned publication space in 1983 in the *Journal of Research in Science Teaching*, rated as the No. 1 journal in science education, worldwide. We found that students in the cooperative-learning group performed best of all in cognitive achievement. They also had the greatest positive attitude change. On practical skills, the competitive group emerged superior.

COGNITIVE ACHIEVEMENT	CP > CM > IN
PRACTICAL SKILLS	CM > CP > IN
ATTITUDE	CP > I N > CM

Having established empirically the potency of the CP strategy, we decided to dig in further within this terrain. Our second and third series of experiments focused on determining which variant of cooperative learning is most predisposing to achievement. We tried the Jigsaw, TGT, and STAD and compared with CP+CM, our emerging model. We found CP+CM to be superior (see Okebukola, 1987 and Table 2).

Table 2: Comparison of achievement of cooperative-learning groups

Group	**Mean**	**S.D.**	**F**
STAD	24.58	3.08	
TGT	20.23	3.11	10.34*
Jigsaw	18.15	2.36	
CP+CM	29.34	2.19	

*p<.001

We rounded up this phase of our work by examining the critical group size and the mix of members within the CP+CM setting. Our findings on the critical group size, that is, how many students should the science teacher allow in a cooperative-learning group for best effect, have remained inconclusive. More work would, therefore, be needed in this area. On the mix of students in the group, we have been able to gather a respectable corpus of evidence from our studies (e.g. Okebukola, 1984; 1985a; 1985b) and from the literature (e.g. Lazarowitz, 1994; Scharman; 1995) that high; average and low ability students in the proportion of 20%:60% and 20% is ideal with a mixed-sex colouration. In sum, our studies converge in suggesting that if meaningful learning of science is the goal in an environment with shortage of equipment and materials, the CP+CM strategy displaying intra-group cooperation with inter-group competition using mixed-ability and mixed-sex groups is potent.

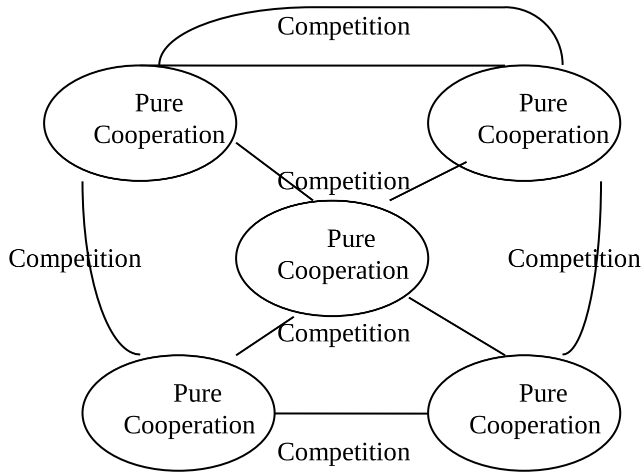

Fig. 1 Intragroup Cooperation with Intergroup Competition

Let us move on now to CONCEPT MAPPING - our "scud missile" that has scored the bull's eye on the barriers to meaningful learning of science.

Concept mapping is one of the three metacognitive tools that was invented by the Cornell school of researchers in the early 70s. The others are vee-mapping and concept-circle diagramming. I have had the opportunity of working with Professor Joe Novak, the leader of the team that invented concept mapping and also Professor Jim Wandersee who developed the vee-mapping technique.

Novak & Okebukola

Concept mapping is a metalearning strategy based on the Ausubel-Novak-Gowin theory of meaningful learning. It relates directly to such theoretical principles as prior knowledge, subsumption, progressive differentiation, cognitive bridging, and integrative reconciliation.

Basic to making a concept map is the ability of the mapper to identify and relate its salient concepts to a general, superordinate concept. That requires an understanding of what constitutes a science concept. Concepts may be defined as regularities in objects or events designated by some label, usually a term. Whether a process (e.g. precipitation), a procedure (e.g. titration), or a product (e.g. carbohydrate), concepts are what we think with in science. Concepts can be connected with linking words to form propositions (e.g. turtles are classified as reptiles, sucrose tastes sweet, ontogeny recapitulates phylogeny). Therefore, a concept map may be defined as ".... a schematic device for representing a set of concept meanings embedded in a framework of propositions" (Novak & Gowin, 1984).

Concept maps can be constructed by students from texts or after class discussions/lecture. It involves listing the main ideas/concepts and words and arranging these in a hierarchy. The most general, abstract and most inclusive (superordinate) concepts are lower down in the hierarchy. This array of concepts is connected by lines or arrows carrying labels in a propositional or prepositional form. At the terminus of each branch may be found examples of the terminal concept. A finished concept map is analogous to a road map with every concept depending on others for meaning.

In constructing concept maps, students:

1. note the keywords/concepts, phrases or ideas that are used during the lesson or read in a text.

2. arrange the concepts and main ideas in a hierarchy from the most general most inclusive and abstract (superordinate) to the most specific and concrete (subordinate).

3. draw circles or eclipses around the concepts.

4. connect the concepts (in circle) by means of lines or arrows accompanied by linking words so that each branch of map can be read from the top down.

5. provide examples, if possible, at the terminus of each branch.
6. cross-link hierarchies or branches of the map where appropriate.

Our exploration of the potency of concept maps in breaking barriers to meaningful learning of science began in 1986. Using two groups of senior secondary biology students, we found the concept mapping group, after five weeks of post-familiarisation treatment, to significantly outperform the control group that did not have the concept-mapping experience in a test of meaningful learning of ecology and genetics - two concepts that are perceived to be most difficult by many SS biology students in Nigeria. Replication of this study in two other sites produced results that conformed our initial findings. We reported these studies in the article *"Attaining meaningful learning of ecology and genetics: A test of the efficacy of the concept mapping technique"*. This article and the one entitled *"Ecocultural influences on students' concept attainment in science"* by Okebukola and Jegede, both published in the *Journal of Research in Science Teaching*, have remained two of our most-cited articles in the science education literature. The instruments that we developed for the study on concept mapping, genetics and ecology have been adapted for use by researchers in the UK, USA, China, South Korea and Nigeria.

We continued with further exploration of the potency of the concept-mapping technique in 1989 and 1990. We found that the strategy enhanced problem-solving skills in science (Okebukola, 1990). Our major contribution turned out to be the use of the concept-mapping technique in a cooperative-learning setting. Our data (see Table 3) showed that individual concept mappers performed less well than students who mapped cooperatively.

Table 3: Comparison of achievement of concept-mapping groups

Group	Mean	S.D.	F
Coop-concept mapping	34.09	4.89	23.76*
Indiv-concept mapping	27.11	4.34	
Control	18.45	3.76	

*p < .001

The article "Concept mapping with a cooperative-learning flavour", published in the *American Biology Teacher*, and "Techniques of concept mapping" published in the *Journal of the Science Teachers Association of Nigeria* summarise the findings of our studies in this area.

Our third technique was the use of analogies. The analogies group in our studies performed significantly better than the control. We used culturally familiar analogies whenever possible in order to connect science concepts to the students' real-world experiences. Occasionally bringing culturally familiar examples into the science classroom makes the learning environment hospitable for all students.

In concluding this report of our studies on breaking barriers to the meaningful learning of science, it is worthy of mention that different styles of learning require teachers to instruct students differently. Some teachers use teaching styles that provide inequitable learning outcomes. Also, good science teaching requires creative science curricula. Students must see how science applies to their lives. If they live in urban areas, they must be able to connect what is happening in a science classroom to what is either happening or should be happening in their communities and lives. Teachers must have the ability to communicate with all their students and create an environment in which all students desire to communicate with the teacher and other classmates.

When students enter the classroom, they bring along with them a complex set of assumptions about the way the natural world works. These children then will struggle to fit whatever new phenomena they encounter through science lessons into their existing understanding. Many times, a child's existing knowledge base - which typically includes many inaccuracies - and his or her new experiences will conflict. As the child's mind gamely tries to force a square peg into a round hole, the peg - a valid science concept - may become damaged. Researchers have termed these damaged understandings "naive conceptions," "misconceptions," or "preconceptions".

Science teachers must determine students' levels of scientific understanding and assist them in learning more science. Since we now know people do not learn at the same rate, why do we continue to expect all students to understand the same concepts in the same depth at the same time? Students do not come with the same life experiences; they view the world differently.

AGENDA FOR CHANGE

Having reviewed the impediments to progress in the delivery of good quality instruction in science and having summarised studies which provide strategies for breaking the barriers to meaningful learning of science, the logical follow-up question is: So what? It is in response to this 'so what?' question that I now propose an agenda for change. I am of the humble view that this agenda, if implemented, would ensure that by 2025, Nigeria would be a respectable member of the global scientific village parading some Nobel Prize-winning scientists and with highly developed technology to make us boast of 100% "made in Nigeria" cars, computers, air-planes, heavy industrial equipment and perhaps, launch satellites in space. A wild dream? Definitely not.

It is not a wild dream because Japan achieved such a feat in a shorter time. South Korea too. With good governance and prudential management of resources, this vision for 2025 could be realised. A lot of credit must be given to the present administration for its brilliant economic policies. If such policies are fine-tuned and sustained in the years ahead, the promised land for Nigeria would be “dead ahead”.

My agenda for change is in two major blocks. The first block is focused on broad issues while the second block addresses narrower issues that oil the system. Lined up on the first block of my agenda are four recommendations. The first is that the present level of illiteracy in the country of about 48% should be reduced to 20% by 2005, 10% by 2010 and 0% by 2020. Putting modern science and technology in the hands of stark illiterates is suicide. The first thing to do, therefore, is to make the people functionally literate before throwing them into the sea of modern science and technology. This agenda calls for a more vigorous pursuit of the goals of Education for All. We appear to be moving at the pace of the snail since the EFA Declaration of 1990. It was agreed in 1990 by way of the Declaration that by 1995 endorsing countries should have significantly reduced their level of illiterate population and by 2000 AD, wiped out illiteracy. By 1995, instead of achieving a reduction, our illiterate population increased.

The Federal Ministry of Education, the National Commission for Mass Literacy, and other arms of government at the national, state and local government level must get together to implement a plan to wipe out illiteracy in Nigeria by 2020. The huge support from UNDP and UNICEF must be put to maximum advantage.

After resolving the problem of illiteracy, we must then ensure that the citizenry so made functionally literate should be made literate in science and technology. In July 1993, Nigeria adopted the UNESCO plan tagged "Project 2000+" on Scientific and Technological Literacy for All. As it is with other plans that we participate in drawing up and endorsing at the global level, we literally stuffed the plan in the cupboard. This is to say that progress in the implementation of Project 2000+ objectives has been slow. The project prescribes formal and non-formal mechanisms for making all Nigerians scientifically and technologically literate sometime in the 21st century. The Nigerian Educational Research and Development Council and the Science Teachers Association of Nigeria are in the vanguard of the implementation of the Project in Nigeria. Our wise men in the Vision 2010 Committee must endorse Project 2000+ and support its rapid implementation.

The third recommendation in my first block of agenda is for Government to ensure an investment of three hundred billion naira (=N=300 billion) in the next ten years in the development of science and engineering infrastructure. Aside from having scientifically-literate citizenry, we require a solid science, technology and engineering infrastructure to leap significantly forward. Those countries that we aspire to be like and maybe surpass in science and technology - Japan, Germany, United Kingdom, Korea and others have made, and are making huge and mid-boggling investments in science and technology infrastructure.

As Shakespeare wrote in Julius Caesar Act V:

> *"The fault dear Brutus is not in our*
> *stars but in ourselves that we are underlings."*

The fault in our being backward in science and technology is not because "the black man is banished to be a slave to the white man" as some negrophobics say, but in ourselves. As it is commonly said *"The soup wey sweet, na money kill am."* Those flashy Japanese cars, Mercedes Benz cars, and the exciting sight of American space shuttles conducting experiments in space have come about as a result of huge investment in science and technology. We risk obvious extinction as a race if we do not act now. It is my recommendation also that beginning from 1998, Government should allocate and release a minimum of 0.5% of the GNP for science and engineering research.

The other block of my agenda for change is focused on seven major recommendations:

1. There should be a major rethinking of our science teacher education programmes. First, admission should be limited to only those who willingly elect to study science education. All attempts to smuggle in the unwilling horses who are rejects from other Faculties, should be resisted. In the area of teacher preparation, if we must continue with the 4-year post-secondary programmes, the education content should be reduced in favour of more science courses. This is a pathway towards increasing the content knowledge of our science teachers.
2. The welfare scheme of teachers generally and science teachers in particular should be significantly improved to motivate and foster commitment. If implemented, the Teachers Salary Scale (TSS) would go a long way at improving teachers' welfare.
3. All science teachers should be members of the Science Teachers Association of Nigeria in order to take advantage of the annual national workshops and conferences where new techniques such as the ones used in our studies are learned. Attendance at these workshops and conferences should be a condition for promotion.
4. There is the need to decongest the overloaded science syllabuses at the Senior School Certificate level. Emphasis should be on quality of content not quantity. The on-going effort by the West African Examinations Council in this regard should be speeded up.
5. Government should put in place and enforce policies that will lead to a drastic lowering of the prices of science textbooks.
6. Greater visibility should be given to environmental education, computer education and population education in our schools.
7. A five-year plan for refurbishing the laboratories of our secondary and post-secondary schools using funds from the Petroleum Tax Fund, Education Tax and other sources should be developed and implemented beginning from 1997.

Conclusion

In this lecture, I have reviewed the science education terrain in Nigeria and identified major obstacles to the delivery of good quality instruction. I have summarised our studies which were targeted at breaking the barriers to meaningful learning of science. Some recommendations have also been made for improvement.

Science education in Nigeria, to which I cast the broad focus of this lecture reminds me of the story of the woman with arthritis who went to the doctor and was given some medication. She came back the following week complaining that the pills gave her an upset stomach. She was given more tablets to treat this side effect. She was soon back in the hospital that the second set of pills made her ankles swell. She was in turn given tablets to treat this, which caused her muscle cramps requiring a fourth set of pills, and so on. By now, the woman feels sicker than when she started. So it has been with science education in Nigeria, mere patchwork of treatment leaving the organism known as science education in a rather comatose state. This lecture is a call (LOUD IN LAGOS) for all to join hands in breaking the barriers to the meaningful learning of science in order to assure us a rightful place in the science and technology-dominated world of the 21st Century.

Acknowledgement

I must now thank all those who supported me as I plodded through my career path. My parents - Mr. & Mrs. D.A. Okebukola, my wife Foluso, and my children, my brothers, sisters and other relations and my colleagues in all the places I had worked and my friends, for their contributions. I thank Professor Olu Jegede my academic twin brother for coming all the way from "down under" in Australia to listen to this lecture. I thank the Lagos State University for giving me the chair of science education. My unreserved appreciation goes to Professor 'Folabi Olumide the foundation Vice-Chancellor of Lagos State University, Professor Jadesola Akande, our past Vice-Chancellor and Professor Enitan Abisogun Bababunmi, the immediate-past V.C., an outstanding scholar, father, brother and friend. Most of all, I give Almighty God the glory for the story of my life.