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THE ONE HUNDRED AND TWENTY-THIRD (123RD)
INAUGURAL LECTURE

"THE MISUNDERSTOOD WORD IN SCIENCE: TOWARDS A TECHNOLOGY OF PERFECT UNDERSTANDING FOR ALL"

By

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Great Students of the University of Ilorin,
Distinguished Ladies and Gentlemen.

Preamble

I am happy for the wonderful opportunity and privilege to stand before you today, 21 February 2013, as the embodiment of what good educational policies can do to an individual, nay a nation, to present the 123rd Inaugural Lecture of this great University of Ilorin, Ilorin, Nigeria, entitled, "The Misunderstood Word in Science: Towards a Technology of Perfect Understanding for All." I wish to appreciate God for His grace on this occasion, which is coming at the twilight of my service with the University of Ilorin. I was promoted a Professor on 1 October 1998, over 14 years ago, but other assignments delayed the Lecture till now.

I am a Professor of Science Education, the first Professor of Science Education with specialization in biology in the University of Ilorin and the only one from the University of Ife Biology/Chemistry Education set of 1975. This Inaugural Lecture is the third in the series of such lectures in science education presented in this University. The first one was presented by Professor Aliyu Abdullahi on 12 December 1991, entitled: "Inflating and Deflating Syndrome in Nigeria's Science Education." The second was presented by Professor Esther Ore Omosewo on 8 November 2012, entitled: "Why Dread the Science of the State of the Universe?"

Introduction

My works in science education have been informed by the presuppositions from Cognitive Science, which derived its own base from the history and philosophy of science, sociology of science and cognitive psychology. This lecture focuses on the problem of teaching and learning science, using secondary school biology as a vehicle, as illustrated in Figure 1.

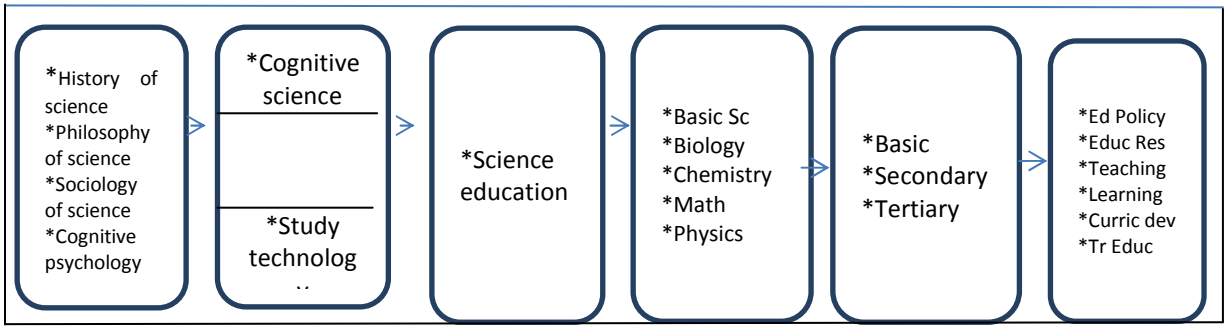


Figure 1: Theoretical bases for science education research

The title of my degree at the University of Ife (now Obafemi Awolowo University, Ile-Ife) is B.Sc. (Education) (Biology/Chemistry). Despite my good teacher education background, it was through Professor Aliyu Abdullahi, that I realized that what I studied is called "Science Education."

Initially, I experienced a conflict in me about the Science I learned in my schools, the science education I was teaching and my background knowledge of superstitious beliefs, when I was growing up. I wondered if the science I learned was as efficacious as I was taught and if so, why did people, including educated ones, still believe in superstitions?

When my feeling of disillusionment persisted, I decided to put my thoughts down in the form of a seminar paper entitled, "African World-view and School Science," (Abimbola, 1977) while I was waiting for letters of admission and approval for university sponsorship to a British or an American university. When eventually I got admitted into the University of Wisconsin-Madison, Madison, Wisconsin 53706, USA, the new reigning research area then was "student misconceptions and alternative conceptions in science" within the cognitive science tradition.

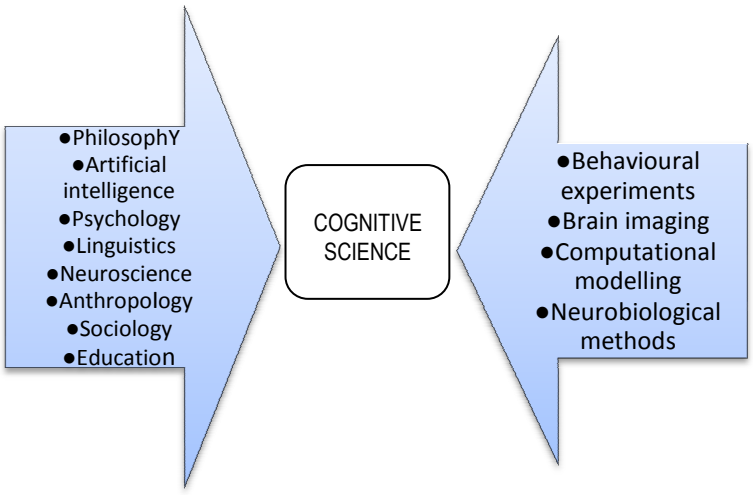
Mr. Vice-Chancellor, Sir, I organized this 123rd Inaugural Lecture as listed below:

(i). Introduction; (ii). The Cognitive Science Research Tradition; (iii). Cognitive Science and Psychology; (iv). Cognitive Science and Philosophy of Science; (v). Cognitive Science and Science Education; (vi). My Encounter with Study Technology; (vii). The Context of Science Education in Nigeria; (viii). My Contributions to

Knowledge, Practice and the Community; (ix). Conclusions; and (x). Recommendations

The Cognitive Science Research Tradition

The theoretical base for my research area is known as "Cognitive Science." "Cognition" is a philosophical term, which means "knowing" or "something known." (Dictionary.com, 2012). Cognitive science, on the other hand, is an interdisciplinary field, which brings together researchers in philosophy, artificial intelligence, psychology, linguistics, neuroscience, anthropology, sociology and education. (Wikipedia, 2012a; Thagard, 2008) (See Figure 2).



Common research methods in cognitive science usually include: behavioural experiments, brain imaging, computational modeling, and neurobiological methods, to enable us understand the relationship between intelligent behaviours and physical systems (See Figure 2).

Cognitive Science and Psychology

"Psychology is the scientific study of mental functions and behaviors" (Wikipedia, 2012c). Cognitive scientists borrow ideas from information processing psychologists and other cognitive psychologists. Common accounts (Hunt, 1982; Lindsay & Norman, 1977) of an information processing model postulate three information stores for human memory (See Figure 3).

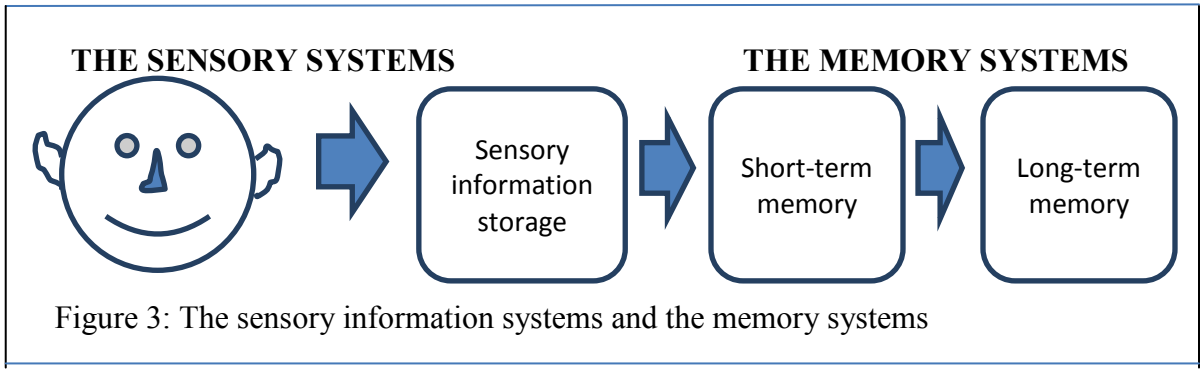


Figure 3: The sensory information systems and the memory systems

Source: Adapted from Lindsay and Norman, 1977, p. 304

The first information store is called Sensory Information Store (SIS). This store is a stage at which humans first become aware of external information.

Second, is the Short Term Memory (STM), where information may be temporarily stored. The information may be retained in the short-term memory for about 18 seconds. For the information to be retained for a longer time, individuals may need to rehearse it to themselves. Approximately seven items of information can be held at one time, "The magical number seven, plus or minus two" (Miller, 1956), which he attributed to the limit of our information processing capacity. The information is there and then lost after a short time, or stored in the third storage system, Long-Term Memory (LTM).

The long-term memory is where information can be stored for ever if it is well processed. This tends to rule out forgetting.

Computers have been used to model human information processing. It is usually done in the form of questions and answers. For a computer, the answers are produced within seconds, but it has to search for these answers each time a question is asked, because of the limit of human knowledge. A human being, on the other hand, is able to determine whether or not it is useful to attempt a search for an answer from the nature of the question. However, computers can also be programmed to do what human beings are unable to do!

Apart from borrowing ideas from information processing psychology, cognitive scientists also borrow ideas from other psychologists. Examples of such psychologists are Piaget (1979), who was both interested in the theory of knowledge and how human intellect develops;

Ausubel (1968) who is interested in the role of previous knowledge in learning; and Kelly (1955) who was interested in "constructive alternativism," or human construction of alternative knowledge. He employed the notion of "man-the-scientist" to characterize this human attribute.

Cognitive Science and Philosophy of Science

"The philosophy of science is concerned with the assumptions, foundations, methods, implications of science, and with the use and merit of science" (Wikipedia, 2012b). Thus, another source of the ideas of cognitive scientists useful in education is the so-called new philosophy of science. The logical empiricists, unlike the new philosophers of science, hold the following received positions about science, which are currently being challenged by the new philosophers of science:

(i) the philosophy of science is not concerned with the processes leading up to a scientific discovery, but it is concerned solely with scientific discoveries, per se;

(ii) formal logic is more useful for analyzing science products as an objective criterion to validate scientific discoveries (Carnap, 1966; Hempel, 1966);

(iii) observations remain the same during scientific revolutions; a new theory is therefore an improvement over the old one. (Hempel, 1965; Kemeny & Oppenheim, 1970); and

(iv) scientific knowledge increases by accretion (Kemeny & Oppenheim, 1970).

Mr. Vice-Chancellor, Sir, in retrospect, this was the philosophy that was dominant during my university days and appeared incompatible with my intuitive knowledge of what science should be all about.

The new philosophers of science, in contradistinction to the logical empiricists, employ the history and sociology of science for the analysis of science (Abimbola, 1981, 1983, 1984). They reject formal logic as the primary tool for the analysis of science. The scientific community decides on any scientific question. They also posit that progress in science oscillates between normal science and revolutionary science, which leads to changes in paradigms or currently shared concepts with the old and new theories not being comparable using the same standards. Observations therefore undergo changes during this period of revolution. These philosophers believe that continuing research coupled with continuing criticism is the core of science. However, some of the new philosophers of science believe in an evolutionary approach to scientific progress and development (Abimbola, 1983).

Cognitive Science and Science Education

Cognitive science research, which has relevance for science education can be discussed under the following headings, which include: (a) Problem solving, (b) Problem solving and conceptual knowledge, and (c) Conceptual change.

(a) Problem solving. Most of the early studies related to problem solving are in the area of mathematics and physics. In some of these studies, the emphasis was not primarily on conceptual knowledge. Thus, no attempt was made to analyze, in detail, the conceptual knowledge of a

problem solver. The researchers were often concerned with differences between how experts and novices solve problems, with more mathematical skills and experience (Simon & Simon, 1978).

(b) Problem solving and conceptual knowledge. Some problem-solving studies have been focused on the conceptual knowledge necessary for solving specific science problems. An early example is the investigation of the conceptual knowledge necessary for meaningful problem solving in genetics by Stewart & Dale (1981) who demonstrated that conceptual knowledge is important for problem solving.

Other studies were devoted to students' conceptions of specific content areas in science, including early studies by Nigerians. All of the studies concluded that misconceptions and alternative conceptions were common among the students involved in the studies. Examples of such studies are: (Abimbola, 1984, Nkpa, 1987, Okeke, 1976, & Taiwo, 1976).

Mr. Vice-Chancellor, Sir, I am happy to report that the research area has moved from an initial stage of serious interrogation and sometimes, opposition, from colleagues in my Department and in science education literature in Nigeria, to one, which is embraced by all science educators and non-science educators in my Department and beyond.

(c) Conceptual change. The conceptual change model of learning views learning as a conceptual change rather than behavioural change. It applies the account of conceptual change in scientific disciplines as proposed by the new philosophers of science to explain the conditions under which students are most likely to change their misconceptions, and alternative conceptions, i. e., what I

now call "the misunderstood words" to scientific conceptions. This model is a constructivist view of learning (Glaserfeld, 1989).

Research based on the conceptual change model has usually followed the pattern of preparing a special unit, the teaching of which will hopefully enable the students change from their conflicting misconceptions and alternative conceptions to acceptable scientific conceptions. Instructions can be designed to effect a conceptual change in the learner, through a three-phase instructional strategy, involving an awareness phase, a disequilibrium phase and a reformulating phase. A gap in this model is how a researcher can use a strategy that is predictable, repeatable, and universal in effecting a conceptual change in students. This is where study technology provides an answer.

The Coincidence of my Encounter with Study Technology

I attended a one-week workshop on Study Technology in Lagos from 23-28 August 2004. It was organized by the Education Trust Fund (ETF) (now Tertiary Education Trust Fund, TETFund), McRae & Co, Lagos and The Applied Scholastics International, Missouri, USA. It is a great eye opener. Nine of us, due to visa problems, missed an opportunity to attend a Master Training Programme in Study Technology in the U.S.

The Training Programme was held two years later in Akure, Ondo State, from 13 April – 20 May 2006. The workshop was very rigorous, holding from 7.00am to 9.00pm, Monday to Saturday for five weeks. It is equivalent to about 20 course credits.

Mr. Vice-Chancellor, Sir, "Study Technology is a research-based system of learning how to learn, which includes basic principles and workable methods for application in the field of study" (Slaughter, 2006, p. 1). It is the Applied Scholastics International's collective name for its teaching and learning methods. The end results of the application of Study Technology are students who know how to learn, how to apply what is learned and are motivated independent lifelong learners. Teachers who know how to use this method become new teachers who know how to teach students how to learn, and they become lifelong learners and teachers who are capable of learning anything and teaching anything and any type of learner!

The Applied Scholastics International identified three major barriers to the learner's study, namely: (i) Absence or lack of mass. (ii) Too steep (skipped) a gradient. (iii) The misunderstood word (See Figure 4).

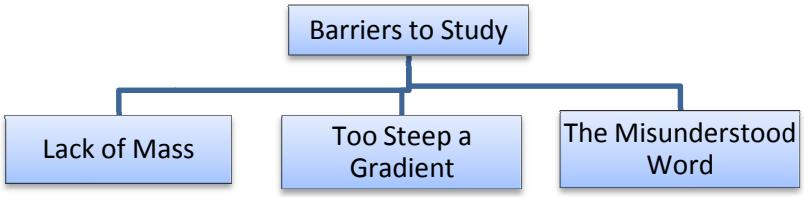


Figure 4: Three barriers to study

Absence or lack of mass. "Mass" is the real thing or object meant for study. When a learner experiences absence or lack of mass, there are some reactions that are exhibited to varying degrees. These are: (i) feeling

squashed, (ii) face squashed, (iii) bent, (iv) sort of spinning, (v) sort of dead, (vi) dizzy, (vii) bored, (viii) angry, (ix) stomach feeling funny, (x) headache, and (xi) eyes hurting frequently.

To remedy the incidence of the absence of mass, the learner is provided with the actual object being studied. It is only when this is not possible that the instructor provides the following as alternatives: pictures, movies, demonstrations, demo kits, clay demos and sketching.

Too steep (skipped) a gradient. A gradient is a way of learning or doing something step by step. There are two reactions associated with too steep (skipped) a gradient during a study situation. These are: (i) Sort of reelingness, and (ii) Confused. In this barrier, the gradient of a learning material is represented by three dimensions, which determine the difficulty of how it would be learned. They are the dimensions of abstractness, complexity and sophistication (Abimbola, & Danmole, 1995). The abstractness of a concept varies from concrete to abstract in terms of its accessibility to observation and visualization. The complexity of a concept varies from simple to complex, in terms of how many other concepts are subsumed by a given concept. This dimension is what contributes the most to concept difficulty in learning (Phenix, 1962). The sophistication of a concept depends on the degree of its refinement for learning purposes. It varies from descriptive level, through comparative level to quantitative level. The easiest concepts to learn are simple, concrete and descriptive while the most difficult concepts to learn are complex, abstract and quantitative.

Figure 5 is a two-dimensional representation of the gradient. The structuring of materials for learning will

move gradually through the ladder to have an appropriate gradient.

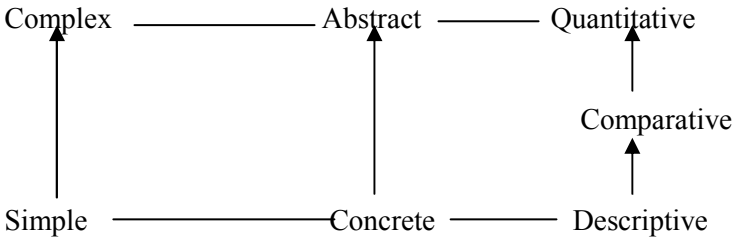


Figure 5: Concept difficulty matrix (2D)

The remedy for too steep (skipped) a gradient is to cut down on the amount of information or steps learned at a time and proceed gradually to ensure that each step is learned completely before moving to another step, repetition of processes is advisable.

The misunderstood word. A misunderstood word, concept, symbol, or situation is a word, concept, symbol, or situation, which is not understood, or a word, concept, symbol, or situation, which is wrongly understood.

Mr. Vice-Chancellor, Sir, the third barrier to study is the most important barrier because it is capable of making learners quit what they are studying about or drop out of school completely. It affects our thinking processes. It is the makeup of the subjects we talk, discuss, or study about. It is the definitions of words. It is the main reason for arguments.

When a learner has a misunderstood word, he or she exhibits some of these listed reactions: (i) Blank, (ii) Sort of nervous hysteria, (iii) May do wrong thing, (iv) Doodling, (v) Daydreaming, (vi) Yawning, (vii) May not remember what you read on page, (viii) A washed out

feeling, (ix) Worried, (x) May stop doing what you are studying about, (xi) May make you stay long on what you are studying, and (xii) May cause blow.

To remedy misunderstood words encountered by learners who are exhibiting the preceding reactions, the instructor assists them to clear the words, using dictionaries. This makes the strategy applicable to any subject of the school curriculum.

Mr. Vice-Chancellor, Sir, Table 1 describes the relationship between the attributes of cognitive science and study technology. This is the first time I am making this comparison, which is not exhaustive, and it promises to be an important contribution in raising awareness about the close relationship between cognitive science and study technology.

Table 1: A Comparison between Attributes of Cognitive Science and Study Technology

S/N	Cognitive science	Study technology
1.	N/A	Availability and use of standard, reference and subject dictionaries
2.	Promotes active learning	Availability of demo kits/Clay work
3.	Availability of course materials	Availability of course materials
4.	N/A	Use of checksheet/study guide
5.	Cooperative learning	Twinship
6.	N/A	Absence of verbal data
7.	Chunking and rehearsal of information to ensure storage in the long-term memory	Use of the Chinese school/Qur'anic school
8.	Involvement of various	Availability of projection

	sense organs in students' learning	equipment
9.	Uses interview and other knowledge assessment techniques	Uses two-way communication during learning sessions and interviews after testing sessions
10.	N/A	On Demand Examination System
11.	Learning how to learn (or meta-learning or meta-cognition)	Learning how to learn and apply
12.	Misconceptions and alternative conceptions	The misunderstood word
13.	Conceptual change	Word clearing is in use
14.	Role of previous knowledge in learning	N/A
15.	Not so prominent	Re-study and repeat exam are some of the strategies
16.	N/A	Study technology is in continual use

The Context of Science Education in Nigeria

The context of science education in Nigeria is discussed under these sub-headings:
(i) Educational policy, (ii) Educational research, (iii) Teacher education, (iv) Curriculum development, (v) Teaching, and (vi) Learning.

Educational policy. A major characteristic of educational policies in Nigeria is policy inconsistency. The policies vary as the Ministers come and go at an alarming rate. For instance, within the last fourteen years that a civilian rule was re-introduced in Nigeria, there have been twelve Ministers of Education, which roughly translates to about one Minister per year.

Since, independence, several conferences and seminars had been held to fashion out educational policies for the country. For example, the 1969 Curriculum Conference held in Lagos from 8-12 September 1969 (Adaralegbe, 1972), was a landmark one. A National Seminar on Educational Policy, based on the earlier conference, was held in 1973 under the Chairmanship of the late Chief Simeon O. Adebo and this led to the production of the first edition of the National Policy on Education in 1977 (FRN, 1977). This was the basis of the 6-3-3-4 system of education.

Later, the Federal Government set up an Implementation Committee for the National Education Policy under the Chairmanship of the late Professor Sanya Onabamiro, to translate the policy into a blueprint that would guide its implementation (FRN, 1979). On the basis of the ***Blueprint***, the ***National Policy on Education*** was revised in 1980 and published in 1981.

Aspects of the National Policy on Education that relate to science curricula at the secondary school level include: (i) science as one of the core subjects at the junior secondary school; and (ii) Biology was specifically listed as one of the core science subjects of the senior secondary school level, along with, Chemistry, Physics, and Health Science.

Work on the National Policy on Education up to 1979 took place under military regimes. At the resumption of civilian regime in 1979, the Nigerian Educational Research Council (NERC) organized the National Seminar on Qualitative and Quantitative Education under the Chairmanship of the late Professor S. O. Awokoya (Nigeria Educational Research Council, 1980). Subsequently, the

third edition of the National Policy on Education was produced in 1998. The fourth edition was produced in 2004, which incorporated the Universal Basic Education programme earlier launched in 1999, the Millennium Development Goals (MDGs), and National Economic Empowerment and Development Strategies (NEEDS). A draft National Policy on Education, which may soon be in use, was produced in 2007.

On Friday, 27 March 2009, a stakeholders' meeting was held with the then Honourable Minister of Education, Dr. Sam Egwu, in which a research-based strategic "Roadmap for the Improvement of Education in Nigeria" was launched. The "Roadmap" included: (i) access and equity; (ii) standards and quality assurance; (iii) technical and vocational education training (TVET); and (iv) funding, resource mobilization and utilization. All these policies have far-reaching implications for all aspects of education, which will be discussed in the next sections.

Educational research. I remarked in 1996 (Abimbola, 1996) that the research scene in Nigeria had not changed a great deal since Abdullahi's (1984) review of science education research in Nigeria. While some of the problems he identified in the conduct of research in science education then have become ameliorated, most of them still persist. For instance, he identified the following as obstacles to research in science education: (i) absence of educational research centres, (ii) inadequate outlets for research findings, and (iii) lack of institutional investment on research in science education.

Concerning the first obstacle, there is yet no recognizable research centre in Nigeria. The Nigerian Educational Research and Development Council, which

should normally be in charge of educational research in Nigeria, is yet to demonstrate sufficient interest in educational research. The institutes of education in Nigerian universities that should also be centres for research have literally taken over the traditional functions of faculties of education in producing teachers through sandwich and part-time programmes. We, science education researchers, too, have yet to form what could be regarded as research groups that could be identified with our universities.

As for outlets for research findings, ***The Journal of the Science Teachers Association of Nigeria*** remains the major surviving outlet for science education in Nigeria. There are other relevant journals in education but they, too, have largely been overshadowed by foreign and online journals, which continue to experience a boom at this time.

Research funding opportunities have increased through the Tertiary Education Trust Fund (TETFund), Senate Research Grants, and other external sources. However, there is no dedicated research funding agency for science education in Nigeria.

Teacher education. The focus of this section is on how the training of secondary school teachers evolved. To produce non-graduate qualified teachers for the lower forms of the secondary school, federal and regional governments established five Advanced Teacher Training Colleges (ATTCs) in 1962. The number of colleges of education performing this function has increased since then. The total number of Colleges of Education in Nigeria as at 5 January 2013, according to MySchoolGist (2012), is about 100, with 21 Federal Colleges of Education, 46 State Colleges of Education and 33 Private Colleges of

Education. The National Teachers Institute, established in 1976, also participates in the production of Nigeria Certificate in Education (NCE) teachers.

When Yaba Higher College was founded in 1932, and formally opened on 19 January 1934, it introduced the secondary school Master's diploma of education course lasting three years for secondary school leavers. The science curriculum of the programme included: "botany, zoology, chemistry, physics, and mathematics in the first year, reducing to three in the second year and to two in the third year" (Taiwo, 1980, p. 80). The Diploma was then awarded in either, (biology and chemistry with physics as a subsidiary) or (mathematics and physics with chemistry as a subsidiary). After the Higher College was merged with the University College, Ibadan, a one-year postgraduate diploma programme was introduced in 1957/58 academic session (Fafunwa, 1995).

Professor A. Babs Fafunwa facilitated the introduction of the B.A. /B.Sc. Education format for preparing secondary school teachers at the University of Nigeria, Nsukka in 1961 with the first graduates produced in June 1964. The University of Ibadan later followed suit in 1963, Ahmadu Bello University in 1964, the University of Lagos in 1965 and the University of Ife in 1967 (Fafunwa, 1995). Secondary school science teachers are now being produced with B.Sc. Education/B.Ed. degrees in two (one major and one minor) or one minor teaching subject(s), respectively.

Other features of teacher education include: the establishment of the Teachers Registration Council of Nigeria (TRCN) to register professionally qualified teachers at all levels of Education in Nigeria. A formal

induction of newly graduated teachers has also commenced; Curricula of Colleges of Education and Universities in Nigeria are being reformed to respond to new realities in teacher education in the country.

Curriculum development. Curriculum development efforts in the world in the sixties received their impetus from the launch of Sputnik 1 on 4 October 1957 by the former Soviet Union. Sputnik 1 was the first man-made Earth satellite. This event, which came as a great surprise, led to a world-wide re-evaluation of science curricula led by the United States of America. Despite the fact that the Physical Science Study Committee (PSSC) had been established at the Massachusetts Institute of Technology (MIT), Boston, USA, in 1956, greater momentum was applied to science curriculum development subsequently.

Other secondary school science curriculum projects in the USA, which followed in quick succession, were Chemical Bond Approach (CBA) (1958), Chemical Education Materials Study (CHEM Study) (1959), the Biological Science Curriculum Study (BSCS) (1959), and the Harvard Project Physics (HPP) (1964).

The initiative for science curriculum development in the United Kingdom (U.K.) belonged to science teachers, unlike the situation in the USA, where science curriculum development was championed by university professors and industry leaders. Between 1957 and 1961, the Association for Science Education (ASE) published the following books: (i) Biology for Grammar Schools (ii) Chemistry for Grammar Schools and (iii) Physics for Grammar Schools. With support from the Nuffield Foundation, the ASE launched the following Nuffield

Science Schemes between 1961 and 1962: Nuffield "O" Level Biology, Nuffield "O" Level Chemistry and Nuffield "O" Level Physics, Nuffield Combined Science, and so forth. The Nuffield science projects in physics, chemistry and biology were trial-tested in Western Nigeria between 1965 and 1967.

Another British secondary science curriculum project was the Schools Council Integrated Science Project, which adopted the "Patterns Approach, a combination of the existing "Process Approach" and "Conceptual Approach."

In fairness to the developed countries of the West, there were early efforts to involve African countries in the race for science curriculum development to improve science teaching and learning in African schools. For instance, as early as 1960, international conferences were held in Rehovolt, Israel and MIT, Endicott House, USA, to prepare the ground for science and mathematics curriculum development in Africa (Yoloye & Bajah, 1981).

The first experiment at re-ordering our secondary school system for better functional education started in the Western Region of Nigeria in 1963 through the establishment of Comprehensive High School at Ayetoro, near Abeokuta. Ayetoro Basic Science Project for Forms I and II of the secondary school was produced between 1962 and 1966. The project was later revised by the Comparative Education Study and Adaptation Centre (CESAC) and published as CESAC Basic Science for Nigerian Secondary Schools (BSNSS) for Forms I and II.

The Science Teachers Association of Nigeria (STAN) was one of the early participants in science curriculum development efforts in Nigeria. It produced

pupil's textbooks I & II, pupil's workbooks I & II, and teacher's guides I & II. With the introduction of the 6-3-3-4 system of education, the materials were revised to cover the first three years of the secondary school system. STAN has since produced STAN Biology, STAN Chemistry, STAN Physics, STAN Agricultural Science, and so forth for the senior secondary school level.

Another major secondary school science curriculum project was the Nigerian Secondary School Science Project developed by CESAC in 1970 based on its alternative syllabus accepted by the West African Examinations Council (WAEC) for use in examining the West African School Certificate candidates. The materials included: Biology textbooks I-III, Chemistry textbooks I-III, and Physics textbooks I-III. Teacher's guides were also prepared for each book. .

The current senior secondary school science curriculum, which was an outgrowth of the one developed earlier by CESAC, was developed in1985 (Federal Ministry of Education, FME, 1985b) to include Agricultural Science, Biology, Chemistry and Physics. The biology section was organized under seven themes. The 2009 edition of the Biology Curriculum (NERDC, 2009) now has only four themes.

Science subjects have lost out in the new senior secondary school curriculum because it is no longer a requirement for senior secondary school students to offer one science subject as a part of the core subjects. The new core subjects are: English language, General Mathematics, Computer Science, and One Trade/Entrepreneurship subject. How do we then produce a scientifically literate society devoid of ignorance and diseases?

The National Curriculum for Junior Secondary Schools in Science (FME, 1985a) was devoted to Integrated Science, Mathematics and Physical Education. The curriculum was based on four themes. The Integrated Science component was revised to Basic Science for JSS 1-3 in 2007 (NERDC, 2007).

Teaching. Most of the science curricula in the sixties emphasized activity based, inquiry, and discovery teaching and learning approaches. Therefore, as science educators in the developed countries exported the science curriculum development initiatives to the developing countries, they also brought in the same methods of teaching, which were implemented half-heartedly because the methods were very tasking.

In an independent country-wide survey of science teaching in 294 secondary schools in the 12 States in Nigeria, Thollairathil (1973) observed that the existing science curricula leaned heavily toward a teacher-oriented teaching programme, with "authoritarian teaching methods" (p. 1) to complete the examination syllabus.

In a more recent country-wide survey, Japan International Cooperation Agency (JICA) (2005) in collaboration with the Federal Ministry of Education, found poor teacher-pupil strategies in operation, monotonous use of lecture method of teaching and inadequate and poor utilization of available teaching materials.

The recent revelations about the quantity and qualifications of teachers in Nigeria, across all educational levels, validated some of these findings. It is also a great irony if several qualified teachers remain unemployed in some States, while some other States are experiencing shortages and are hiring unqualified teachers. For instance,

Vanguard (2012) labeled Kaduna State, "Home of fake teachers" as revealed by two Kaduna State Commissioners and its Governor, because 18,000 basic school teachers possessed fake certificates and had been sacked, while only about 50% of primary and secondary school teachers possessed required teaching qualifications.

Furthermore, the Honourable Minister of Education, Professor Ruqayyatu Rufa'I, herself, (Daily Trust, 2012) claimed that the number of qualified teachers in the Basic Schools throughout Nigeria did not exceed 91% at the Junior Secondary School level, while Early Childhood Care and Development Education (ECCDE) had 70%; and Primary School had 73%. However, all stakeholders appear to be sitting up to address the capacity problems at various levels of education. For instance, by the end of 2012, about 40,000 Basic School teachers had been trained by the National Teachers' Institute, Kaduna, Nigeria. In addition, Dr. Precious Gbeneol, the Special Adviser to the President on the Millennium Development Goals, 722,736 Basic School teachers had been trained since 2006 under her watch (PM News, 2012).

Learning. The system of education in Nigeria provides little opportunities for students to engage in self-instruction because they are always being taught by either teachers in schools or coaching classes, or parents and siblings at home, without knowing how to study by themselves, with the exception of, perhaps, students in boarding schools.

In addition, the school and examination systems do not encourage them to master any content completely. Most continuous assessment tests and other examinations require them to answer only a proportion of the whole questions

set; never all questions. The reward system is also along the same line. Generally, 70% score in an examination is regarded as an excellent score. This situation does not naturally encourage students to strive harder to score 80s and 90s. Study technology has an important role to play in this area.

For a long time, we seem to have accepted the poor performance of students in the final West African School Certificate and National Examinations Council Examinations as the norm, without being able to do much about it. For instance, Omolewa (1981) showed that candidates had been underperforming in Cambridge external examinations since 1914, based on available records, with the percentage performance falling below 50% except in 1914 (See Table 2).

Table 2: Enrolment and Candidates' Performance in the Cambridge Examinations (1914-1922)

Year	No of entries	% Pass
1914	53	50.90
1917	109	(*)
1920	110	41.50
1921	137	38.00
1922	303	40.00

*No result, examination papers were lost at sea during the First World War

Source: Department of Education. Nigeria. **Annual Reports**, 1913-1922

Similar figures were shown for candidates' enrolment and performance in the West African School Certificate Examinations by Kuti (1976) in the sixties. The

performance level for the years for which data were available all fell below 35% (See Table 3).

Table 3: Enrolment and Candidates' Performance in the West African School Certificate Examinations (1960-1968)

Year	No of entries	% Pass
1960	6,143	32.36
1963	10,766	27.64
1968	19,313	24.19

Source: Kuti, M. A. O. (1976). The need for counseling in Nigerian secondary schools. ***Journal of the Science Teachers' Association of Nigeria, 15***(1), 29-30.

Furthermore, the overall national enrolment and performance figures for the years 1995 to 2012, all fell below 35%, except in the year 2012, which rose to 38.81 in the major school subjects (See Table 4).

Table 4: Overall National Enrolment and Performance in the West African Senior School Certificate Examinations (1995-2012)

Year	Total Entry	Total Sat	Credit Passes	No of Subjects	%
1995	466,971	464,270	N/A	N/A	N/A
1996	630,633	516,196	N/A	N/A	N/A
1997	643,060	618,139	154,535	18 Subjects/ 12 Subjects	≤25 ≥25
1998	721,986	636,777	N/A	N/A	N/A
1999	822,054	757,233	N/A	N/A	N/A
2000	643,378	636,044	N/A	25	≥25
2001	1,099,987	1,025,185	N/A	N/A	N/A
2002	1,240,163	925,289	231,322	28	≥25
2003	1,0066,831	939,507	234,877	25	≥25
2004	1,035,280	1,020,431	N/A	30	≥25
2005	1,080,162	1,064,587	266,147	22	≥25
2006	1,170,522	1,154,266	276,793	31	23.98
2007	1,270,137	1,252,570	280,826	29	22.42
2008	1,292,910	1,274,166	369,636	32	29.01
2009	1,373,009	1,355,725	405,768	27	29.93
2010	1,331,381	1,307,745	305,489	34	23.36
2011	1,540,141	1,514,164	467,877	34	30.90
2012	1,695,878	1,672,224	649,156	N/A	38.81

Source: The West African Examinations Council, Zonal Office, Enugu, Enugu State, Nigeria.

The performance level for the individual science subjects did not show any significant rise for a twenty-year period between 1991 and 2011, except occasionally for Chemistry and Physics, which were above 50%. Candidates' performance in biology over these years never rose above 50%, perhaps because non-science students used to register for biology as a core science subject (See Table 5).

Table 5: Candidates' Performance in May/June Senior School Certificate Examinations in Biology, Chemistry and Physics in Nigeria: 1991-2000

Year	Biology			Chemistry			Physics		
	Total Sat	Credit Passes	%	Total Sat	Credit passes	%	Total sat	Credit passes	%
1991	285,690	72,988	25.60	116,526	12,117	10.30	96,742	17,037	16.80
1992	355,582	99,919	28.10	140,856	26,763	19.00	122,809	20,018	16.30
1993	481,034	138,057	28.70	170,537	39,224	23.00	152,276	37,155	24.40
1994	508,384	57,956	11.40	161,232	38,212	23.70	146,000	21,462	14.70
1995	453,353	85,684	18.90	133,188	48,880	36.70	120,768	22,825	18.90
1996	506,628	80,554	15.90	144,990	48,572	33.50	132,768	16,994	12.80
1997	609,026	96,226	15.80	172,383	40,682	23.60	157,700	14,824	9.40
1998	634,021	218,420	34.45	185,430	39,682	21.40	172,223	19,530	11.34
1999	745,102	207,213	27.81	223,307	69,404	31.08	210,271	64,280	30.57
2000	659,020	127,256	19.31	201,369	64,217	31.89	193,052	58,031	30.06

Source: Statistics Section, WAEC National Head Office, Yaba, Lagos, Nigeria;
WAEC Branch Office, Oko Olowo, Ilorin, Kwara State, Nigeria.

Table 5 (Contd.)

Candidates' Performance in May/June Senior School Certificate Examinations in Biology, Chemistry and Physics in Nigeria: 2001-2011

Year	Biology			Chemistry			Physics		
	Total Sat	Credit Passes	%	Total Sat	Credit passes	%	Total sat	Credit passes	%
2001	995,345	231,418	23.25	301,740	109,381	36.25	287,993	99,242	34.46
2002	882,119	278,112	31.52	268,824	90,488	34.90	254,118	120,768	47.76
2003	909,101	392,249	44.15	282,120	143,839	50.93	275,369	130,982	47.65
2004	1,027,938	253,487	24.69	269,774	105,133	38.94	265,262	135,359	51.04
2005	1,072,607	375,850	35.04	349,996	178,274	50.91	344,411	142,943	41.53
2006	1,152,045	559,854	48.60	308,104	170,670	55.34	375,824	218,199	58.16
2007	1,238,163	413,211	33.37	422,681	194,284	45.92	218,593	180,797	43.24
2008	1,259,964	427,644	33.94	418,423	185,949	44.47	415,113	200,345	48.38
2009	1,903,552	644,733	33.87	422,091	194,035	45.97	429,174	186,940	43.56
2010	1,300,418	427,644	33.90	465,643	236,059	50.70	463,755	237,756	51.30
2011	1,505,199	579,432	38.50	565,692	280,250	49.54	563,161	360,096	63.94

Sources: Statistics Section, WAEC National Head Office, Yaba, Lagos, Nigeria;
WAEC Branch Office, Oko Olowo, Ilorin, Kwara State, Nigeria.

In sum, secondary school students have been consistently performing poorly in the final West African School Certificate Examinations. To do something about this situation, the West African Examinations Council once organized a seminar on students' performance in public examinations at the Conference Centre of the University of Ibadan on Friday, 24 April 1992. The Science Teachers Association of Nigeria (STAN, 1992) participated in the seminar and made far-reaching recommendations. Recently, an annual stakeholders meeting has been organized by the Federal Ministry of Education after the release of the results of the May/June West African School Certificate Examinations.

Despite this poor performance trend, with the implication that only few candidates are thereby qualified for admission into higher institutions, the admission trend, too, is very poor. Despite progressive increase in the number of universities in the country, the admission rate between 1995/1996 academic session and 2007/2008 academic session has been slow in improving (Jekayinfa, Yusuf, Yahaya, & Yusuf, 2010). The percentage of candidates admitted did not reach 20% during the period, except 1998/1999 academic session when it was 23.09%.

Some of my Humble Contributions to Knowledge, Practice and the Community

Research. (1) I have been at the forefront of raising awareness about the research area of students' misconceptions and alternative conceptions in science, including its philosophical roots, when the research area faced the problem of acceptance (Abimbola, 1986a, 1986b, 1986c, 1987, & 1988b). I have also done a lot to promote

its new variant, the misunderstood word, locally and internationally (Abimbola, 2011).

(2). There are seven major themes in the former senior secondary school biology curriculum in Nigeria (Federal Ministry of Education, FME, 1985). I am happy to report that my students and I have researched into five of the themes. (i) Concept of living—Bello (1990) & Obe (1989); (ii) Ecological concepts—Abidoye (2012), Aworanti & Abimbola (1997), Bolakale (2007), Oyebanji (2002), & Oyedeji (2005); (iii) Plant and animal nutrition—Abimbola (1986d), Ahmed (2003), & Ahmed & Abimbola (2011); (iv) Evolution—Ajibade (1995), Bello & Abimbola (1997) & Oni (1992); and (v) Genetics—Oyeyemi (1991).

(3). I contributed a validated example of a strategy for sequencing curricular content using a logical approach, where all key words in a text are defined and sequenced in their logical order of mention before I knew about study technology (Abimbola, 1984). This was used to demonstrate that if content is logically valid, it should be psychologically valid, too, because it would coincide with the level of the intellectual development of learners and the way information is stored in their brain.

(4). In research settings, I established that clinical interview technique can be used wholly and successfully for student assessment in biology (Abimbola, 1985). It is also useful for detecting misunderstood words held by learners and for verifying their knowledge after each test or examination.

(5). I established a list of important but difficult biology topics in the senior school biology, as perceived by biology teachers, for use in research, curriculum development, instruction, teacher education and educational policy in Nigeria (Abimbola, 1998). I used the list to improve the

biology course offerings of our students by focusing more on pure biology than applied biology.

(6). We established that misconceptions and alternative conceptions exist in biology students, teachers and textbooks. Hence, this emphasizes the need for all to aim at perfect knowledge to minimize or eliminate the incidence of student misconceptions and alternative conceptions in science. Related examples are: (i) Students—(Abimbola, 1984, 1986d on human respiration; Aworanti & Abimbola, 1997 on ecology concepts; Bello & Abimbola, 1997 on evolution concepts; (ii) Teachers—Abimbola, 1984, 1986d on human respiration; and Olatunji, 2005 on biology concepts; (iii) Textbooks—Abimbola, 1991; Abimbola & Baba, 1996. Critical experiments performed on ***STAN Biology*** showed it to be technically difficult to read, two grade levels above the school certificate level, and contained misconceptions and alternative conceptions, despite its expert touch.

(7). Other relevant and significant contributions are: Abimbola (1987) & (1992); Adeyemi & Abimbola (1993); Abimbola & Mustapha (2003); Abimbola & Omosewo (2012); and Ayanda, Abimbola, & Ahmed (2011).

(8). I contributed to the refinement of the terms used for describing student conceptions in science through philosophical analysis (Abimbola, 1988a; Abimbola & Danmole, 1995; Abimbola & Yarroch, 1993). This lecture is a further contribution in this direction as "the misunderstood word" is an attractive and useful descriptor for what students fail to understand well.

(8). We proposed models for describing the interactions in students of disciplinary knowledge, curricular knowledge, experiential knowledge and students' personal knowledge (Abimbola & Danmole, 1995; Abimbola & Yarroch, 1993). (See, e. g., Figure 7)

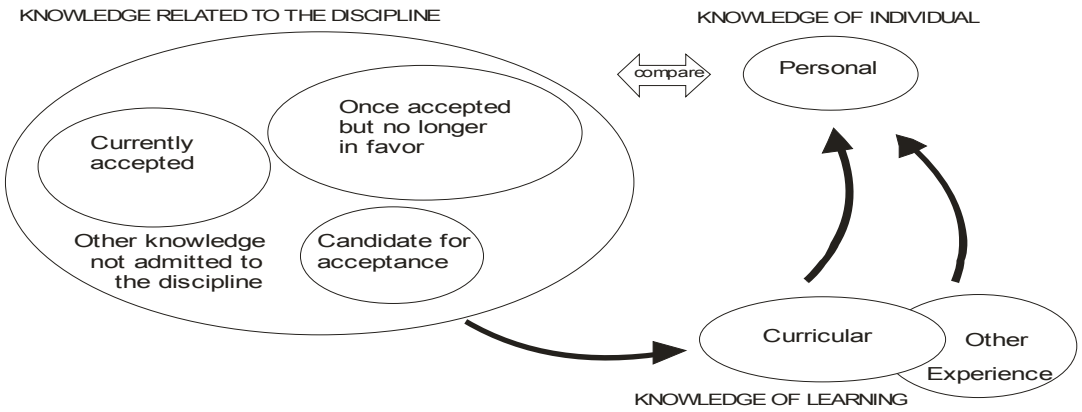


Figure 7: A model depicting interactions among disciplinary knowledge, curricular knowledge, experiential knowledge, and personal knowledge

(9). Research work in progress—Collaboration with colleagues in the College of Health Sciences, Faculties of Engineering and Technology, Communication and Information Sciences and Education. We are constructing an artificial model of the brain for teaching purposes, with appropriate mapping of the visual, auditory and olfactory pathways using texts, electrical wiring and concept mapping.

(10). I have contributed my own quota over these years to the production of high level personnel for Nigeria's higher institutions by producing 34 M.Ed. and 8 Ph.D. graduates in Science Education or Curriculum Development.

(11). Topics for my undergraduate student research projects since 2006/2007 academic session were based on selected themes that were usually not adequately covered in regular subject methodology courses to ensure that our biology education students can compete favourably as competent, efficient and effective teachers. Examples of the themes for their research project topics are:

(a) 2012/2013—Barriers to Learning in Selected Biology Lessons.
(b) 2011/2012—Causes of Biology Candidates' Poor Performance WASSCE.
(c) 2009/2010—Preparation of a Checksheet for Teaching a Unit of Biology.
(d) 2008/2009—A Model of an Organ or System in Biology.
(e) 2007/2008—Multiple-choice Test Items for Assessing Biology Students.
(f) 2006/2007—Lesson Plans for Teaching Secondary School Biology.

(12). In the realm of ideas, my critique of the report of the 1969 National Curriculum Conference (Adaralegbe, 1972) and the 1981 edition of the National Policy on Education (FRN, 1981) of the inconsistency and the inappropriateness of the uses of "purposes," "aims," "goals," and "objectives" led to a revision of the "national objectives" to "national goals" in the third edition (FRN, 1998) of the National Policy on Education (Abimbola, 1993a).

(13). I make bold to say that my works on history and philosophy of science (Abimbola, 1981, 1983, 1986c, 1987) formed part of the corpus of works in our Department (e. g., Abdullahi, 1976; Abimbola, 1981, 1983, 1986c, &1987; & Olorundare, 1985) that influenced the introduction of History and Philosophy of Science as a General Studies Course, and as an additional requirement for all science education students in Nigerian Universities. I contributed and taught two of the early authentic History and Philosophy of Science topics in the course (GNS 311)—(i) The Structure of Science and (ii) Scientific Method and Revolutions in the University of Ilorin. These topics have remained in the relevant GNS book since then.

Professional Practice. (1). I taught study technology to all students, undergraduates and postgraduates, who passed through me, to enable them know how to learn by themselves, apply what is learned and become life-long learners and their scores in relevant examinations have been improving since then.

(2). Study and Teaching Technology (PDE 604) was unanimously introduced into the University's Post-Doctoral Diploma in Education online programme by the Faculty Board of Education and was approved by the University

Senate. It is also a new course in the revised master's degree programme of the Department of Science Education.

(3). I wrote a booklet for JSS Integrated Science where research-based misunderstood words in the three science subjects of biology, chemistry and physics were used as distractors in multiple-choice questions. It was written within the best traditions of the principles and practice of Measurement and Evaluation. The booklet sold in 11 deliberately selected States of Nigeria over a period of 8 years until it was rested for revision purposes.

(4). As a retired West African Examinations Council Examiner for Biology, I observed that senior school certificate candidates did not usually have complete understanding of definitions of major concepts in biology. I then wrote a booklet containing the definitions of key concepts related to the major themes of the senior secondary school biology to address this problem.

(5). I established my philosophical credentials by writing one book each on History of Science and Philosophy of Science in response to one of the assessors of one of my philosophical papers in 1983 who encouraged me to convert the paper into a book later for use by science teachers.

(6). I have strove to influence the way student teachers are prepared and how practising teachers teach by producing a booklet on Lesson Planning for student teachers of colleges of education and universities. It was distributed free of charge to all lecturers in the Faculty of Education in 2007 for use in teaching their methods courses.

Community Service. (1). I was the only person teaching Science Methods as a single course (I & II) usually offered at both the 200 and 300 levels at the inception of the University of Ilorin, Ilorin, Nigeria. Because of this experience, I was instrumental in splitting the course into three: Biology Methods I& II, Chemistry Methods I & II, and Physics Methods I & II, in 1994.

(2). I collaborated with other seven Applied Scholastics International Instructors in providing basic training (10 days) in study technology for 50 Lecturers of the Federal College of Education, Okene, Kogi State, Nigeria. The programme was sponsored by the Tertiary Education Trust Fund (TETFund) in collaboration with the Applied Scholastics International, Missouri, USA and McRae& Co., Lagos. The programme took place in all Federal Colleges of Education in Nigeria.

(3). I have single-handedly trained 248 secondary school teachers in study technology in three secondary schools in Ilorin, Kwara State, Nigeria, to assist teachers to know how to learn and apply their knowledge and be able to teach their students well.

(4). The contents of my proposal for the establishment of a Study Technology Centre were incorporated into the programmes of the Centre for Research, Development and In-house Training (CREDIT), after the University informed me officially that it would not be able to approve my proposal.

(5). I was the Team Leader, when eight other Applied Scholastics International Instructors and I, trained 292 Senior Lecturers, Readers and Professors of the University of Ilorin, Ilorin, Nigeria, in Study Technology as the

Foundation Director, Centre for Research, Development and In-house Training (CREDIT).

Conclusions

The following are my major conclusions from the lecture:

- Cognitive science and study technology share several important attributes, which are useful for understanding how students learn, and for removing students' misunderstood words in science.
- Student teachers in science need to be good university candidates *ab initio*, for any format of teacher education programme to produce competent, efficient and effective science teachers from them.
- Science subjects have lost out in the new senior secondary school curriculum because they are no longer among the core subjects to be offered by all final-year students.
- Teacher-centred methods of teaching science predominate in Nigerian secondary schools.
- Our system of education does not encourage students to excel in their studies because of its structural defects in setting low standard of performance.
- Senior School Certificate candidates have consistently been performing poorly overall, but particularly in science subjects.
- Less than 20% of applicants for university admission are usually admitted every year leaving over 80% without admission.

- Biology students and teachers hold deep-seated misunderstood words.
- Biology textbooks contain misunderstood words.
- There are tested strategies for writing good science textbooks and courseware.
- Study technology is useful for all who yearn for perfect understanding.

Recommendations

1. All teachers should communicate correct information to their students at all times, through well structured written instructional materials such as checksheets or study guides, or courseware, without verbal instruction.
2. All basic and secondary school teachers should be encouraged to submit themselves to promotion examinations in their teaching subjects and pedagogy, as Kwara, Bayelsa, Osun and Ekiti States are already doing, to achieve the goal of perfect understanding of their discipline and profession.
3. The Tertiary Education Trust Fund (TETFund) should resume its training programmes in study technology and make them available to all higher institution teachers.
4. The goal of perfect understanding is achievable by both textbook authors and publishers. Textbook authors and publishers, therefore, need to familiarize themselves with the logical structure of the content materials they intend to present to learners so that they can present them in a manner that is correct, with major concepts well defined before and within the text and in a manner that will

tally with the way information is stored in the learners' brain. They need to use many knowledge representation techniques, such as concept maps, v-maps, and generous use of analogies, metaphors, and so forth in their textbooks.

5. There is a strong need for teachers and other examiners to deliberately improve the standard of education in the country by increasing the amount and variety of work given to students either as exercises or as tests, which stand the chance of raising the stake of such activities to enable students attain perfection in their knowledge. Teachers and examination bodies should stop giving questions with options to examinees; they should be made to answer all questions in all formats.
6. The grading system at all levels of education in Nigeria needs a complete overhaul, whereby the cut off points for different grades are jacked up, as a first step, as follows:

Excellent	90-100	A	First Class
Very Good	80- 89	B	Second Class (Upper Division)
Good	70- 79	C	Second Class (Lower Division)
Fair	60- 69	D	Third Class
Poor	50-59	E	Pass

This general overhaul would encourage all categories of students to positively change their attitude to their school work while their teachers learn how to grade students' work in the new system.

7. The Joint Admissions and Matriculation Board should incorporate Aptitude Test as the fifth subject

in its Unified Tertiary Matriculation Examinations (UTME) to encourage candidates to prepare ahead for such a section in a manner that would prepare them for higher education, the world of work and life, in general. This would make the UTME to become both an achievement test, and an aptitude test for predicting success potential in higher institutions.

8. Student teachers in colleges of education and universities should be exposed to innovative methods of instruction during their training to enable them implement such upon graduation.
9. As a first step, study technology should be incorporated into all subject methodology courses in the University of Ilorin.
10. Quality Assurance Units of the Federal and State Ministries of Education and Local Education Authorities should be upgraded and adequately funded to be able to perform their statutory duties efficiently and effectively (Abimbola, 1993b).
11. To continue to produce teachers who are competent, efficient and effective on the job, there is a strong need for Federal and State Governments to resuscitate teachers' bursary as a way to deliberately encourage brilliant students who are interested in the teaching profession to elect to study education courses in the University.
12. Parents should ensure that they give correct information to their children at home. They should not misrepresent information for them in the name of simplification. In addition, they should provide a

rich environment for their children, where quality self-instruction can take place.

13. To engender overall peace within and among individuals in the Nigerian and the global societies, there is a strong need to cultivate the habit of effective communication to avoid the incidence of misunderstood words, symbols or situations. This is one of the ways to achieve the goal of perfect understanding for all in the society.

Appreciation

I wish to appreciate all of you for honouring me today. The under listed groups of people deserve attention for their roles in my career and life:

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