

**TRANSFORMING BIOLOGY EDUCATION IN NIGERIA  
THROUGH COGNITIVE-CONSTRUCTIVIST MODELS:  
INTEGRATING HIERARCHICAL AND HEURISTIC  
LEARNING STRATEGIES**

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**Abstract**

*The teaching of Biology in Nigeria remains largely teacher-centered and focuses on memorization rather than understanding of concepts. This position paper supports cognitive constructivist models of instruction, namely Hierarchical Task Analysis (HTA), Cognitive Task Analysis (CTA) and the Heuristic Model Learning Strategy (HMLS) as a systematic foundation of effective change in the teaching of Biology. These models are based on the theory of Piaget, Vygotsky, Bruner, and Sweller that offer practical approaches to promoting inquiry, thinking, and creativity among students. The paper also uses theoretical basis and empirical research studies in Nigeria and other nations to give a synopsis of research studies that prove constructivist and heuristic strategies are effective in enhancing learning outcomes of students in science. It also indicates*

*situational factors including poor instructional materials, insufficient teacher preparedness and the existing examination culture which hinders creativity in classroom practice. The paper asserts that HTA, CTA and HMLS should be integrated into biology teaching and learning, teacher education, and curriculum development as this is crucial in attaining significant educational change. It also argues that the transition to cognitive constructivist pedagogy is not to be merely perceived as a theoretical project but rather as a pragmatic reform agenda that would not contradict the National Policy on Education (FRN, 2013) and Sustainable Development Goal 4 on Quality Education. This paper concludes that the implementation of these models will lead to better conceptual knowledge, critical thinking, and problem-solving skills that can be used to create a scientifically literate citizenry that can be found in Nigeria by addressing potential implementation challenges and giving practical recommendations on policies, curricula and pedagogy.*

**Keywords:** Cognitive-constructivism, Biology Education, Hierarchical Task Analysis (HTA), Cognitive Task Analysis (CTA), Heuristic Model Learning Strategy (HMLS).

### **Introduction.**

Education is always the driving force of national change and science education in particular takes the center stage in facilitating innovation and sustainable development. The National Policy on Education (Federal Republic of Nigeria (FRN), 2013) in Nigeria focuses on producing scientifically literate persons, i.e. learners with the appropriate levels of scientific knowledge, skills and attitudes that can help them to comprehend the world around them, use scientific concepts to manage daily life, and become productive participants in the technological and socio-economic development of their country. Biology in this policy context plays a central role since it provides students with the necessary knowledge of life processes, environmental sustainability, health and human well-being, which are all vital in the development of an individual and the nation at large.

Despite this central role, empirical studies indicate that Nigerian secondary school learners have been experiencing relatively low performance in Biology over the years. Research papers by Etobro and Fabinu (2017) and Magashi (2021) are based on the analysis of the external examination outcomes and present consistent poor results in the Biology category of interaction with a consecutive group of learners. This trend does not imply that students of Biology represent another population compared to those students who excel on other subjects, it only tells that a rather similar group of students who show fairly good performance on other science and non-science subjects tend to perform relatively worse in biology. This kind of tendency indicates an instructional problem that is subject-specific but not indicative of a generalized lack in the academic capability of students.

A number of empirical studies have proposed that the current challenges that Biology learning outcomes are reporting in Nigeria can be linked to the fact that traditional and teacher-centred teaching methods still dominate the country. According to evidence provided by national assessment reports, the teaching and learning in most Biology classrooms is more focused on memorization of the factual material rather than on the reasoning, inquiry, discovery, and application of knowledge (West African Examinations Council (WAEC), 2018, 2019). Based on this observation, Etobro and Fabinu (2017) estimated that teaching of Biology at a secondary school in Nigeria is mostly lecture-oriented and therefore students are deprived the chance to participate actively in building of knowledge or constructive classroom interaction.

Recent researches also suggest that instructional practices that are teacher-dominated are more likely to situate the students as recipients of information, rather than participants in the learning process, which is likely to limit conceptual knowledge and ability to develop higher-order thinking skills (Usman et al., 2023; Nwankwo et al., 2024). Theoretically, these patterns of instructional delivery are indicative of the characteristics of a transmission-focused pedagogy that places

a high premium on the external delivery of information and low levels of learner engagement. The modern body of learning science studies warns of a possible diminished capacity of students to learn to establish theoretical knowledge of biology with real-life situations in science, which influences meaningful learning and long-term memory (Kirschner et al., 2018).

To address these constraints, there has been an increasing demand in the educational research and policy communities to have teaching methods that rebrand learners as agents of creating biological knowledge. Modern educational research is therefore shifting towards the more learner-focused based and inquiry-based pedagogical practices that would enable the learners to develop as critical thinkers and creative contributors to the scientific problem-solving process. This change in pedagogy is manifested in key international education policy frameworks such as the *Reimagining Our Futures Together* (2021) by UNESCO, which promotes the redesign of classroom teaching in order to support deep learning, creativity, inclusivity, and lifelong learning, and also in the Sustainable Development Goal 4 of the United Nations which encourages the transformation of classroom learning practice to support deep learning, creativity, inclusivity, and lifelong learning. These policy guidelines are very similar to the concepts of cognitive-constructivism that theorize learning as an active, reflective, and socially mediated process where learners construct meaning by interacting with the ideas, their peers, and environment.

With the rising focus on the learner-centred and inquiry-based teaching methods promoted by recent educational studies and international education systems, the focus has been progressively directed to those teaching methods that shift teaching toward active interaction with material, thinking, and questioning, rather than merely transferring information passively. These reforms are based on the cognitive-constructivist principles which consider learning as a participatory, socially mediated and reflective process as has been argued in the foregoing discussion. There are numbers of pedagogical

frameworks that have been put forward and implemented in the practice of science education, as well as in Biology. The most noticeable ones include the Hierarchy Task Analysis (HTA), the Cognitive Task Analysis (CTA), and the Heuristic Model Learning Strategy (HMLS) that are all aimed at active engagement of the learners in building and using biological knowledge.

Hierarchical Task Analysis (HTA) is a method of instructional planning that entails the breakdown of complex subject content into sub-tasks that are logically arranged and organized, thus helping learners to advance the already known simple concepts into more complex biological functions. By means of such hierarchical structuring of the material, HTA facilitates instructional scaffolding, assists in the control of the cognitive load, and makes sure that the proper knowledge is developed before the learners can proceed with the higher-level reasoning. The success of this method is supported by empirical evidence in Nigeria. Indicatively, Omotayo and Osuala (2023) established that senior secondary school students who studied Biology by a task hierarchy analysis model performed much better in their academics and showed more favorable perceptions about the subject compared to those who studied Biology through the traditional teaching methods. These results indicate that sequence or order of tasks can be used to improve success and student interest in Biology.

Cognitive Task Analysis (CTA) builds on the concept of traditional task analysis as it is considered not only the observable steps of the instruction, but also the deep processes of thinking and reasoning as well as metacognitive abilities of an expert when performing a task. Creating explicit links between expert thinking, CTA is designed in a way that helps learners to understand the application of knowledge in real-life situations in the scientific world. Even though there is a general shortage in direct empirical research specifically referred to as CTA taking place in the environment of Nigerian Biology classrooms, the related studies on guided discovery and problem-solving strategies indirectly back the premises of its assumptions. An

example of this is that students who were exposed to the guided discovery strategies in Biology performed better and were capable of retaining concepts as compared to those that were taught using lecture-based teaching (Egbes and Ajaka, 2025). These results are consistent with the major assumption of CTA that knowledge-application knowledge improves conceptual mastery and helps to develop expert-like thinking when implemented into instructional design.

The Heuristic Model Learning Strategy (HMLS), on the contrary, focuses on inquiry, discovery learning, and problem-solving as the main elements of the teaching process. The heuristic methods stimulate learners to investigate biological phenomena, formulate hypotheses and test them, build explanations, thus appealing directly to the higher order mental processes. Although empirical research that clearly looks at HMLS use in the Nigerian Biology classrooms is yet to be experienced, some of the related constructivist and interactive teaching methods have shown similar positive effects. As an illustration, research carried out in Cross River State has revealed that students who had Biology lessons based on interactive and student-centred teaching methods performed much better compared to those who had the lessons through traditional methodology, which sets an example of the importance of learning through exploration and interaction by the learner. Likewise, a study by Olayinka (2016) and other Nigerian studies about concept mapping as a strategy that is usually placed on the heuristic and constructivist models also proved to provide better achievement and retention rates among students in Biology, which also proves the efficiency of the approach based on discovery.

Despite the fact that empirical studies that directly compare the Cognitive Task Analysis with Heuristic Model Learning Strategy in the Nigerian Biology classroom settings are still scarce, the available literature on hierarchical instruction, guided discovery, interactive instruction, and constructivist pedagogy offers formidable empirical and theoretical support to the ideas that the latter needs to be

implemented. Together, HTA, CTA, and HMLS can be seen to take the cognitive-constructivist theory and turn it into the actionable instructional models through encouraging a system of scaffolding, inquisitive deliberation, and active participation of learners. These models when systematically integrated into the Biology curriculum planning and classroom practice have significant potential of enhancing conceptual, reasoning and scientific dispositions of students than those commonly realised in the case of traditional, teacher-centred methods.

### **Theoretical and Conceptual Framework**

Cognitive-constructivism combines both the perspectives of cognitive and constructivist epistemology, which assumes that learning happens through active construction of meaning, but not passive absorption of information (Chand, 2023). The model shares that the learners come to new learning situations with existing knowledge, process the experiences through existing schemas and keep on reorganizing those schemas through reflection and interaction. The emergence of HTA, CTA and HMLS is rooted in this theoretical tradition, and it was based on the works of Jean Piaget and Lev Vygotsky, Jerome Bruner and John Sweller. Further review are presented on these.

### **Piaget's Cognitive Constructivism.**

The theory of Jean Piaget is the basis of the comprehension of the way people construct knowledge by interacting with the environment asserting that learners actively build their own understanding through direct experience rather than passively absorb information (Erawati & Adnyana, 2024). He offered learning as an adaption process where new information is assimilated into the existing cognitive structures, and accommodation where there is a transformation of the cognitive structures to allow the incorporation of new experiences (Piaget, 1971). This is a cyclic process which results in cognitive equilibrium, in which learners develop a coherent level of understanding of phenomena.

Application of Piaget concepts in the teaching of Biology means that the learner should have both direct observation, experimentation and handling of the materials to put together correct concepts of how life processes work. As an example, learners do not memorize light reaction and carbon dioxide, rather, they should research how light and carbon dioxide influence the growth of plants. The Hierarchical Task Analysis (HTA) puts this principle in translation to the instructional design by breaking down complex subjects into successive tasks that are cognitively suitable to students. In this way, structured interaction enables learners to transition through the experiences they have in concrete operations to abstract reasoning so that they come to realize more.

#### **Vygotsky's Sociocultural Theory.**

Lev Vygotsky developed the constructivist paradigm by outlining its learning in the context of a social and cultural environment. At the heart of his theory is the Zone of Proximal Development (ZPD) that characterizes the gap between what learners are capable of functioning without and what they are capable of performing with the assistance of a more competent peer or educator (Vygotsky, 1978). Consequently, cognitive development relies on the social interaction and scaffolding, which helps learners to accomplish tasks that are slightly above their current level of competence (Wu & Bakar, 2025).

Cognitive Task Analysis (CTA) fits the Vygotsky schools of thought since the expert reasoning is explicitized. Teachers assist pupils in internalizing scientific thinking processes through the use of modeling, questioning and guided practice. As an example, instructor teaching genetics may show how to use Punnett squares to predict the results by explaining the logic behind every step. With time, students learn to adapt this mental process and this means they are able to solve problems independently. This will turn classrooms into collaborative learning environments where direct discussion and facilitation of discovery will substitute memorization.

### **Bruner's Discovery Learning**

Jerome Bruner brought constructivism a step further by laying more emphasis on discovery as the most influential way of learning. He hypothesized that as learners are prompted to explore, hypothesize and experiment, they learn more and transfer knowledge more (Bruner, 1961). The philosophy of Bruner has been utilized to come up with the Heuristic Model Learning Strategy (HMLS). It makes students investigators who formulate meaning in the forms of inquiry as opposed to passivity.

Heuristic learning in the case of Biology instruction utilizes students in real-life enquiries, including observing ecological interactions or looking through a microscope in order to investigate microorganisms. These events instill curiosity, toughness and logical thinking. HMLS also strengthens metacognition, because students are able to consider the investigation processes that they underwent; they analyze the evidence and narrow down the conclusions. The higher-order cognitive skills necessary in lifelong learning are also stimulated by such reflective participation.

### **The Cognitive Load Theory of Sweller.**

The Cognitive Load Theory takes the place of constructivist models as John Sweller explains the limits of the working memory when learning. Sweller (1988, 2016) stated that the instructional design should address three cognitive loads, including intrinsic, extraneous, and germane. HTA and CTA work together to achieve this balance; sequencing tasks in a logical manner and eliminating needless complexity. When studying cellular respiration, cognitive overload is decreased and the bigger concept is divided into smaller, manageable concepts, leading to better understanding.

These theories offer a wholesome approach to changing Biology learning by integrating the constructivist ideologies with cognitive effectiveness. HTA is focused on the systematic development, CTA is concerned with the cognitive modeling, and HMLS promotes creative investigation. They collectively represent a pedagogy that

regards construction of knowledge to be active, social and reflective.

### **Empirical and Contextual Evidence**

A growing amount of international and Nigerian studies found positive results of cognitive-constructivist and scaffolded instructional models in science education. A combination of cognitive and motivational modules at the undergraduate level and used as multi-site interventions had a mean effect size of about  $g = 0.30$  in cases where the interventions were administered over a semester (Cromley, Perez, Kaplan, Dai, & Balsai, 2020). This impact was also especially high on organismal and evolutionary Biology courses, which indicates that even non-intensive, cognitively informed instruction can have a great impact on student achievement (Kaplan et al., 2019; Cromley et al., 2019). This data proves that the interactive resource of cognitive support in conjunction with motivation-oriented scaffolds has a quantifiable and reproducible effect on the conceptual mastery of Biology.

In Nigeria, the quasi-experimental research is used to offer parallel evidence in the secondary-school level. Nwafor and Nwanekezi (2018) explored the synergistic effects of guided inquiry and hierarchical task analysis (HTA) in the teaching Chemistry, which can be conceptualized as transferable to study Biology since similar cognitive tasks are required (students often struggle to recognize and apply foundational concepts learned in one discipline (such as chemical energy principles in chemistry) when learning related material in another (such as biological energy processes in biology) because successful transfer requires cognitive recognition and application of previously learned knowledge across contexts (Seidel, Tanner & Ebert-May, 2020).. In their research which involved 30-item Chemistry Performance Test in Imo State, they found that students taught using the Guided Inquiry Learning Strategy (GILS;  $n = 57$ ) had better performance (Mean = 21.92, SD = 6.57) compared to their baseline score (12.21 (SD = 3.49). While those who were taught using the Lecture Method (LM;  $n = 51$ ) had smaller gains. The ANCOVA proved group differences at  $\alpha = .05$  to be significant and

indicated the practical benefits of guided inquiry and task decomposition in the form of HTA.

More information is gained through quasi-experimental research in Ebonyi State which compared a constructivist teaching methodology with a traditional lecture method among senior secondary students in Biology. The mean score (adjusted) of constructivist group ( $n = 138$ ) was 66.19 ( $SD = 14.27$ ), and the control group ( $n = 146$ ) had the mean score of 47.60 ( $SD = 11.09$ ). Despite the absence of a significant method-by-gender interaction result, females had a slight advantage in the constructivist instruction, which suggests inclusive advantages of various learners (Aja, Chukwuemeka, and Elom, 2024). These results support a fact that constructivist pedagogy enhances understanding and interaction across demographic borders.

Survey-based research is used as a supplement to these experimental results in that it finds out where heuristic and task-analytic strategies can have the most classroom effect. Conducted survey on **400** SSII students in Lagos disclosed that the subject areas of cell biology, genetics and ecological relationship were considered to be the most conceptually challenging subjects. The results of ANOVA showed that the **demographic groups ((gender and school type)** did not have significant differences,  $F(2, 397) = 1.523, p > .05$ . The possible remedies of such topics with practical, heuristic, and inquiry-based teaching, to make them less abstract and more meaningful, were always proposed by respondents (Etobro & Fabinu, 2017).

There are other pieces of evidence of success of scaffolded instruction in the region. Two studies carried out in Taraba State with the Instructional Scaffolding Achievement Test ( $KR-20 = .87$ ;  $N = 240$ ) found significantly higher achievement and retention scores to the students who were taught using the scaffold teaching strategies compared to the students taught using the lecture method. The outcomes of the research revealed medium-to-large applied effects which supported the hypothesis that scaffolding allows achieving the sustained understanding even in Nigerian classrooms with limited

resources (Joda, 2019).

To support these results, Adewumi and Adeoye (2023) investigated the effects of two instructional methodologies and mental capacity on the performance of students in abstract concepts of Biology. They reported that the main effect of the instructional strategy was significant ( $F(2,174) = 15.82, p < .05$ ) with a significant interaction between the instructional strategy and the mental ability ( $F(4,174) = 3.41, p < .05$ ) taking a factor of 180 students in Kwara State. The cognitive-constructivist method enhanced the performance of low and medium-ability learners which validated its differentiating advantages to various cognitive groups.

In a similar work on teacher professional practice, Magashi (2021) analyzed existing empirical studies on the recurring problems in the field of Biology education and discovered that more than 68% of teachers surveyed still relied on teacher-centered instructional methods. However, the constructivist workshop-based interventions enhanced teacher confidence and student participation in inquiry by approximately 25% of the teachers, which emphasizes the interaction between teacher preparedness and inquiry by students. The results support the idea that the professional development in HTA and CTA can change the classroom practice.

In addition, Etim and Okoro (2020) examined the heuristic approach of teaching students in senior secondary schools in Biology in Akwa Ibom State. Their quasi-experimental design included 160 students and reported that the mean post-test score of the heuristic group (68.41) was significantly higher than the mean score of the lecture group (49.33),  $t(158) = 6.42, p < .05$ . The reasoning and retention abilities of the students were also enhanced in the heuristic method four weeks after delayed post-test, implying long-term and short-term learning effects.

Additional evidence in the world demonstrates the same. Gonul, Takmaz, Hohenberger, and Corballis (2018) discovered that

hierarchical structuring can facilitate cognitive development, in experimental paradigms of language and reasoning tasks. They find that conceptual hierarchies are more easily acquired and transferred by learners in cases where knowledge is divided into smaller manageable subtasks, suggesting that HTA is neurologically valid as a scaffold to support the learning process. Similarly, Biswas, Kinnebrew and Segedy (2014) proved that self-regulated learning in computer-based Biology models enhances metacognitive control and conceptual memory during several sessions.

The combination of cognitive and constructivist approaches to instruction improves students' attitudes toward Biology, enhancing both their motivation and affective engagement. As an example, in a sample of 210 students in secondary schools, Okeke and Ogbuanya (2022) reported that heuristic-based instruction raised the self-efficacy scores of students by 27 percent as compared to the lecture-based teaching ( $t(208) = 5.83, p < .01$ ). This effect was attributed to greater learner autonomy and that they could now connect biological theory to real life situations. These findings suggest that, besides improving cognition, cognitive-constructivist strategies can be used to promote long-lasting motivation and academic persistence.

The cognitive load theory is a conceptual framework that can be used to explain these outcomes. Teachers can eliminate extraneous cognitive load by scaling complex biological problems into hierarchical sub-tasks and scaffolding them, thus, allowing germane processing to dominate, thus, enhancing conceptual organization and long-term encoding (Sweller, 1988). Studies on self-regulated learning also indicate that metacognitive cues, feedback loops, and goal-oriented planning, which are major components of CTA and heuristic learning, play significant roles in enhancing the use of strategies and accuracy in helping students solve problems in complex areas of study (Biswas, Kinnebrew, and Segedy, 2014).

Taken together, these results add up to the creation of the solid empirical basis of applying the cognitive-constructivist pedagogies,

specifically HTA, CTA, and HMLS, into teaching Biology in Nigeria. In the international and local settings, there is sustained evidence that the models lead to significant gains in achievement, motivation and retention. Factorial and ANOVA-based analyses establish the significant main effects and interactions in support of constructivist methods at the levels of ability, gender, and contexts. In addition, heuristic and scaffold-based teaching bring about less cognitive loads, development of critical thinking, and improved retention despite low resource conditions. These convergent findings give a solid evidence-base to entrench cognitive-constructivist approaches into the Biology curriculum in Nigeria to enhance the conceptual knowledge, inquiry, and scientific literacy.

Despite the successes of constructivist, scaffolded, or heuristic instructional methods on the results of many Nigerian studies (Etim and Okoro, 2020; Joda, 2019; Adewumi and Adeoye, 2023), the results are mostly due to the short-term intervention experiments under the supervision of the researcher. They thus are instructionally effective but not long-term classroom implementation and curriculum change (Cromley et al., 2019; Kaplan et al., 2019). As a result, the availability of evidence has not been correlated into systematic pedagogical transformation since teacher-centred instruction prevails in the majority of secondary schools (Magashi, 2021). Besides, previous researchers usually explored each strategy separately instead of combining them to form an instructional system (Etim and Okoro, 2020; Nwafor and Nwanekezi, 2018; Joda, 2019). There is thus no well-defined framework of the literature that operationalizes the conglomerated use of HTA, CTA, and HMLS in the routine biology teaching in Nigeria. The problem with biology education in Nigeria is therefore not an indication of efficacy but rather failure to organize the integration. The given gap is filled by the current paper, as it suggests a detailed cognitive-constructivist implementation model that covers both curriculum design and assessment practice as well as teacher preparation. This changes the subject of the research on validating interventions to implementation and reform of education.

### **Position and Rationale**

The overall argument that is pursued in this paper is that the secondary biology education system in Nigeria has to move away as a rote, teacher-centered teaching system towards a cognitive-constructivist one, which incorporates the Hierarchical Task Analysis (HTA), Cognitive Task Analysis (CTA), and the Heuristic Model Learning Strategy (HMLS). This stance is not just hypothetical, but it is based on cognitive psychology and backed up by empirical evidence, and it is consistent with national and world educational priorities.

This argument is based on four pillars that are closely interconnected. First, cognitive-constructivist models align with the natural processes of human learning. Learners do not acquire knowledge passively; rather, they actively construct understanding through mental organization, experimentation, and reflection (Piaget, 1971; Vygotsky, 1978; Bruner, 1961). Organizing lessons using Hierarchical Task Analysis (HTA) enables teachers to scaffold complex topics, such as genetics or ecological interactions, into sequenced tasks that correspond to learners' cognitive development and reduce cognitive load (Sweller, 1988; Sweller, 2016). Similarly, Cognitive Task Analysis (CTA) promotes higher-order thinking by making expert reasoning processes explicit, thereby allowing students to internalize scientific problem-solving strategies through guided modelling and practice (Vygotsky, 1978; Bruner, 1961).

Second, these models are supported by empirical data that support academic achievement, motivation and retention. The research has been done in Nigeria and other settings where it has been demonstrated that learners exposed to constructivist, or heuristic strategies achieve higher results than learners taught with traditional strategies. Combining HTA, CTA and HMLS hence presents a research-based strategy to solve the long-standing chronic under performance that has long characterized biology education in Nigeria over the decades.

Third, the use of cognitive-constructivist pedagogy is consistent with the national policy priorities in Nigeria. The National Policy on Education (FRN, 2013) requires instructional strategies that enhance creativity, self-reliance and problem-solving - exactly the skills that constructivist learning cultivates. In the same way, Sustainable Development Goal 4 focuses on the quality education and lifelong learning of every person, which the models operationalize at the classroom level.

Lastly, these models promote the larger socio-economic agenda of Nigeria. With the current trend of technological progress and environmental challenges, biology education should bring about citizens who are able to use the scientific knowledge in addressing real life issues. Such abilities are developed in cognitive-constructivist models, which combine conceptual knowledge with questioning and critical thinking.

Therefore, reform as an appeal does not imply dismissal of the current frameworks but rather a proposal to revamp the current structures using evidence-based pedagogy. A complete re-evaluation of biology education in Nigeria using HTA, CTA, and HMLS is therefore not only an intellectual but also a moral responsibility of the country to empower learners with the competencies they require to compete at both the national and the global level.

Rather than just giving counterarguments, this paper also provides corresponding responses.

Although the theoretical and empirical charm of the cognitive-constructivist models is undeniable, it is against the theoretical and empirical nature of these models that critics tend to raise practical questions about resource availability, teacher readiness, the culture of examination and classroom management. All these are valid concerns but none constitute an insurmountable obstacle.

The initial significant criticism claims the lack of resources. Nigerian schools do not necessarily have fully equipped laboratories, multimedia tools or even access to simulations based on the internet. Nonetheless, the use of cognitive-constructivist approaches does not necessarily require high costs of equipment. The HTA and HMLS are able to be successfully applied with the use of the locally available materials (Joda, 2019; Etim & Okoro, 2020). An example is where a field study of the local ecosystem may be done through fieldwork, whereas the study of plant physiology may be conducted with ordinary items like leaves, containers, and sunlight. Heuristic focus on the discovery helps the teacher and student to improvise to meet the pre-existing limitations instead of relying on the advanced technology.

The second issue is that of teacher preparedness. Nigerian teachers received most of their training based on the traditional paradigms that focus on content delivery and not guiding the inquiry Magashi (2021). But this difficulty brings to the fore the necessity of focused professional growth as opposed to an excuse to spurn changes. The programmes provided in teacher training may include HTA, CTA, and HMLS as the methodology courses. Constant support can be offered through in-service training camps, mentorship programmes and online learning groups. These institutions as the Science Teachers Association of Nigeria (STAN) and Tertiary Education Trust Fund (TETFund) can be crucial in the capacity building.

The third objection is associated with the exam culture in Nigeria. It is common that teachers and students do not focus on inquiry, but rather prepare tests because they believe that activities that are open-ended will mitigate against syllabus coverage. In response to this, the assessment agencies like West Africa Examination Council (WAEC) and National Examination Council (NECO) have to gradually make changes in their question design to encourage reasoning, analysis, and application over rote memorization. A number of education systems, such as Singapore and Finland, have demonstrated that the revision of the assessment systems leads to innovation in pedagogies

(Ketonen & Nieminen, 2024). The same path can be taken by Nigeria by incorporating the reasoning questions in the national examinations.

The fourth and, probably, the most ongoing criticism is large classes, especially in the state schools where one teacher can be over five hundred students. Although this is a challenge to individualized instructions, it does not eliminate the cognitive-constructivist approaches. Cooperative learning, peer tutoring, and jigsaw activities are the types of techniques that can be used to share responsibility among the learners and promote collaboration and accountability. In case the students are made to do HTA-structured assignments or undertake heuristic inquiries in small groups, they acquire knowledge through each other and enhance social skills as well as scientific thinking.

Finally, the arguments used to oppose cognitive-constructivist reform point to the difficulty in implementation, rather than the theory itself. The Nigerian situation requires ingenious adjustment and not an outright rejection of innovativeness. The successful change, as the global experience and domestic experimentations can prove, is not based only on the resources but on the attitude, devotion, and pedagogical perspective.

#### **Implications of Policy and Curriculum.**

The revolution within the field of biology education by the use of cognitive-constructivist models cannot happen in a vacuum; it needs coherent policy change, curriculum redefinition, and institutional orientation. The National Policy on Education (FRN, 2013) already stipulates the learner-centered pedagogy in Nigeria, however, its application has been rather sporadic (Jabaar & Oyewumi, 2018). To close this gap, the Nigerian Educational Research and Development Council (NERDC) needs to change the Biology curriculum to incorporate the hierarchical task design and inquiry-based tasks at each senior secondary level. Instead of delivering information in unrelated form of facts, the topics need to be arranged in a sequence

based on the HTA principles (from basic to complex) in such a way that information is provided in a logical cognitive order of development.

The facilitator of this reform is teacher education. Universities and Colleges of Education need to include explicitly HTA, CTA, and HMLS in their courses of professional methodology. Potential Biology teachers ought to be taught to break down messages, model thinking, and heuristically explore. The same case with continuous professional development applies to in-service teachers who have significantly been working under didactic paradigms. National workshops, seminars and shared online platforms might offer forums through which educators might exchange classroom innovations and perfect constructivist practices. Professional learning communities supported by TETFund and sponsored by Science Teachers Association of Nigeria (STAN) may perpetuate reflective practice and research.

The other important dimension is assessment reform. The prevailing rote learning is supported by the prevalence of recall-based tests. To refocus pedagogy on constructivist goals, the systems of assessment need to reward thinking and questioning. WAEC and NECO can introduce re-designed questions, which demand the student to interpret data, describe processes or research on experimental design. Project work, laboratory reports and reflective journals should also be assessed in schools. When measurements are done on both the process and the product, teachers and students will focus on the deeper learning rather than on superficial memorization.

Moreover, cognitive-constructivist reform must be integrated in terms of policy. The new pedagogy must be incorporated into the national standards of teachers and the science curricula models and monitoring systems in the Federal and State Ministries of Education. Meanwhile, institutions of higher learning ought to carry out continuous studies to assess the efficacy of HTA, CTA, and HMLS in the Nigerian settings, producing evidence that could be used to

improve the policy. This institutional synergy will make reform non-epochal.

The last policy implication is related to equity. The constructivist pedagogy democratizes the process of learning because it allows students to learn by participation not by privilege. It bridges the performance gap between high and low ability learners through the provision of scaffolded support and many points of entry to learning. By incorporating these models in the system of Nigerian education, it is confirming the fact that good science education is not the prerogative of wealth.

### **Implementation Framework**

Although theoretical and empirical justification of the need of reform is high, the practical way of implementation should be planned. The suggested framework is characterized by three intersecting stages that are aimed at creating a balance between ambition and feasibility.

Phase One: Pilot and Capacity building (Annual 1-2).

The stage is aimed at the creation of teacher competence and the experiments on the real classrooms. Master trainers trained in national workshops spearheaded by NERDC, STAN, and universities will relay information to the states and schools. Lessons on the core Biology topics (ecology, genetics, and physiology) that are based on HTA and HMLS can be applied in pilot schools in the six geopolitical zones. The response of these pilots will be used to revise instructional materials and assessment means.

Phase Two: Years 3-5 Preparation of Curriculum and Assessment.

When the successes of pilots are confirmed, the curriculum specialists will assist the examination bodies in harmonizing the standards and learning outcomes. This stage focuses on growth and quality maintenance. Examples of task analysis and heuristic inquiry will be incorporated by textbook writers and developers of digital content. The teacher training institutions will also include cognitive-constructivist modules in the certification form.

Phase Three: Continuous Evaluation and Institutionalization (Years 6-10).

Cognitive-constructivist pedagogy is institutionalized at this point. The ministries of Education will also create monitoring systems to trace the application in the classroom, the performance of the students, and the teacher response. Innovation will be maintained via research grants by TETFund and other agencies primarily by classroom-based research. There will be further incentives such as reward schemes to schools that prove to be excellent in inquiry-based teaching of Biology.

The effectiveness of this framework relies on the cooperation of the stakeholders; policy makers, curriculum developers, teacher educators, examination boards and the teachers themselves. Implementation must not be considered a top-down contribution but as a mutual process towards excellence in education. Every stage offers space to be reflective, offer feedback and be adaptive, and this way, the reform will be context responsive and not prescriptive.

### **Conclusion**

All arguments and evidences used in this paper bring to one point of view; it is necessary and possible to transform the biology education in Nigeria on the basis of cognitive-constructivist models that comprise HTA, CTA, and HMLS. All these models redefine the classroom as a dynamic zone of enquiry where the learners form, challenge and use knowledge instead of memorizing isolated facts. With the help of matching pedagogy to the knowledge of cognitive science, teachers have the opportunity to develop curiosity and resilience qualities without which scientific literacy and innovation are impossible.

Employing the cognitive-constructivist techniques also promotes the national objectives outside the school. The scientifically literate citizenry enhances the ability of Nigeria to overcome the most significant challenges including health crisis, environmental

degradation and food insecurity. When students learn to think biologically by reasoning and exploring, they have higher chances of becoming professionals in the science field, help in the advancement of technology and be able to participate in finding solutions to the problem in the society in a responsible manner.

The process, however, requires joint effort. The government agencies need to offer facilitating policies, universities need to train teachers who are capable of thinking critically, and teaching reflectively, and schools need to adopt inquiry-based assessment. Similarly, science education should be encouraged in communities through the appreciation of curiosity, experimentation, and evidence-based thinking. This is the only way that Nigeria will achieve the transformational potential of cognitive-constructivist pedagogy.

Finally, HTA, CTA and HMLS are not just instructional methods, but a philosophy of learning in which the learner becomes the central figure in the construction of knowledge. These models can transform the use of biology education in Nigeria to memorization, versus mastery, conformity, versus curiosity, and passive learning, versus discovery. Not just an educational dream, such change is a precondition of creating a generation that will determine the scientific and technological future of Nigeria.

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