Nuclear Chemistry as a Difficult Topic for Secondary School Students: Harnessing the Power of Indigenous (Cultural) Knowledge for its Understanding

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Introduction

The knowledge and practice of chemistry is as old as humans. Chemistry as a science subject has over the years contributed immensely in improving our quality of life. It helps to increase food production, preservation and storage with a view to eradicating malnutrition; production of medicinal drugs to enable people enjoy good and healthy life; and production of synthetic fibres used for wide range of clothing materials. Chemical engineers who create fabrics that offer special, stain-resistant properties are also designing technologically advanced fabrics that come out of the dryer without wrinkles or creases.

In the transportation sector, chemistry has made possible the production of suitable fuels for the different types of engines as well as production of different structural materials for building construction. A quick example in this regard are paints and epoxy sprays that are used to protect shelters from the wear and tear inflicted by rain, wind, sun and pollution.

These space-age coatings and paints are designed to make properties look better, perform better and last longer. Thermochemical compounds are also used to protect rooftops and also help structures stay at the right temperature. These chemical compounds have been proven to reduce energy costs and to create a more comfortable shelter for use as a private residence, business centres, place of worship, or any other purposes. Clearly, chemistry is at the centre of our everyday life.

As a result of the improvements in agriculture, health, energy production and manufacturing capabilities that the knowledge of chemistry and its applications provide, there have been noticeable increases in population, average life expectancy and the consumption of material goods. However, these very successes have brought with them their own problems. The increasing population of the planet which was 1 billion in 1800 (in the early days of successive agricultural and industrial revolutions) is set to exceed 9 billion by 2050, faces the prospects of shortage of food and drinking water, severe depletion of key resources from ‘endangered elements’ to biological species and products, pollution of the planetary environment that risks damage to climate systems and ecosystems, and emerging and re-emerging diseases that pose severe threats to health security of the globe. To this end, chemistry must do what it does best - play a central role in tackling these global challenges, including through addressing the Sustainable Development Goals that the world’s governments collectively adopted at the United

Nations meeting in September 2015 and to do so effectively, a radical repositioning of the field of chemistry will be required (Matlin, Mehta, Hopf & Krief, 2015).

Chemistry, from the foregoing is no doubt a unique and an important subject whose knowledge of is truly dear to humans. Yet, it is a subject that is considered difficult by students (Chu and Hong, 2010). According to Özmen, DemİrcİoĞlu, & Coll (2009) whatever difficulty and misconception students experience in understanding chemistry concepts, it is because of the manner in which they are taught. Mihindo, Wachanga & Anditi (2017) also noted that despite the importance attached to chemistry, students' performance in the subject at the national examinations in many developing countries remain poor.

Chemistry educators echo that curriculum for the chemistry of secondary school should be designed to give students the opportunity to be actively involved in the process of learning. This will enable students to solve and decide their daily life problems based on scientific attitudes and noble values. It will also help to develop a dynamic and viable community in line with the latest scientific information and technologies (Ratamun & Osman, 2018). Thus, the chemistry curriculum should lay emphasis on the acquisition of knowledge and mastery of science process skills through practical learning approaches.

It is against this background that this study investigated chemistry concepts found difficult to learn by African students and to harness the power of indigenous knowledge to reduce or remove the difficulties associated with learning any of the most difficult concepts in senior school chemistry.

Survey of topics that senior school students find difficulty with in chemistry

A mixed-method (quantitative and qualitative) design was adopted to collect data for this study. In doing so, two instruments were developed; the Difficult Concepts in Chemistry Questionnaire (DCCQ) and the Difficult Concepts in Chemistry Interview Guide (DCCIG).

Participants

Participants in this study were 1,292 chemistry students from nine public and 12 private senior secondary schools in Lagos and Ogun state, Nigeria and Accra, Ghana. Randomly, 12 schools were selected from Lagos state, eight schools from Ogun state and one school from Accra. About 51% of the respondents were females while about 49% were males. Larger percent of the schools covering about 75% were schools in the urban areas of Lagos, Ogun and Accra. When categorised by school type, 35.1% of the respondents were from private schools while 64.9% were students of public schools.

Validation process and data collection

The DCCQ was used to collect quantitative data for the study. It had five sections. Before section A is on demographic Data. Section B had 22 concepts drawn from the national curriculum for chemistry in Nigeria and Ghana placed on a three-point rating scale of very difficult, moderately difficult and not difficult.

The validation exercise was conducted by 12 experts in science education, the exercise required that some concepts be expunged from section B on the basis of content validity just as section D was scrutinised to ensure construct validity. The validation team also recommended that a section on related factors be added to the instrument in other to strengthen its reliability, hence section C which was not in the first and second draft. Section E was the last section which contain open-ended item on suggestions for improvement. The test-retest reliability coefficient of 0.74 was obtained for the instrument

The Difficult Concepts in Chemistry Interview Guide (DCCIG) was the qualitative instrument used to elicit responses from the 10 randomly selected participants comprising two females and eight males from 2 public schools and three private schools. The instrument contained only 3 basic questions; List three concepts you consider most difficult to learn in chemistry? Please explain why you find each of these concepts difficult to learn. Please suggest ways by which understanding of these concepts can be made easy for chemistry students.

Findings

To determine the difficulty level of each of the 22 concepts highlighted in the questionnaire as perceived by the students, the data gathered were subjected to mean rank analysis. Table 1 shows the result of the analysis.

Table 1: Ranking of difficult concepts in chemistry (*N = 1285 - 1288*)

S/N	DIFFICULT CONCEPTS	MEAN	MEAN RANK
1.	Organic Chemistry – Benzene and its Compounds	2.18	1st
2.	Nuclear Chemistry	2.17	2nd
3.	Salt analysis (qualitative analysis)	2.17	2nd
4.	Volumetric analysis (Titration)	2.16	4th
5.	Chemical equations and equilibrium	2.10	5th
6.	Alkanols, Alkanals and Alkanones	2.10	5th
7.	Acid-Base titration calculations	2.07	7th
8.	Solubility	2.02	8th
9.	IUPAC nomenclature	2.01	9th
10.	Lipids, soap and detergent	1.95	10th
11.	Electrolysis	1.93	11th
12.	Oxidation and Reduction (Redox reactions)	1.90	12th
13.	Chemical bonding	1.89	13th
14.	Hydrocarbons	1.86	14th
15.	Electronic configuration	1.75	15th
16.	Gas laws	1.73	16th
17.	Separation techniques	1.73	16th
18.	Atomic structure and theories	1.72	18th
19.	Metals, Non-metals and their compounds	1.70	19th
20.	Kinetic theory of matter	1.65	20th
21.	Acids, bases and salts	1.64	21st
22.	Periodic Table	1.56	22nd

As seen in table 1, organic chemistry – Benzene and its compounds (M = 2.18) is perceived as the most difficult concept in senior school chemistry, followed by nuclear chemistry and salt analysis with equal mean value (2.17), while volumetric analysis (M = 2.16) ranked the fourth most difficult concept and the least is periodic table periodic table (1.56). Further, table 1 showed that chemical equations and equilibrium, alkanols, alkanals and alkanones, acid-base titration calculations, solubility and IUPAC nomenclature in addition to the aforementioned concepts are perceived as most difficult in senior school chemistry with mean value ranging from 2.01 to 2.18 with concept number 5 and 6 having the same mean value as compared to the mean of other concepts which are below 2.0.

Nuclear chemistry as a topic in senior school chemistry curriculum

As shown in table 1, nuclear chemistry is second in the rank of difficult concepts in chemistry. The choice of nuclear chemistry as against benzene and its compound which is the highest in the mean rank analysis was informed by two fundamental reasons. The amount of information on benzene required of the learners as stipulated in the curriculum for senior school chemistry in Nigeria and Ghana for example is superficial and elementary as compared to nuclear chemistry which is quite robust. Secondly, a quick look at ten years past questions of the reputable examination body in West Africa – WAEC, revealed that questions are rarely asked on benzene and its compounds as compared to nuclear chemistry.

The national curriculum for Nigeria and Ghana stipulates that chemistry students are expected to learn the following contents in nuclear chemistry at senior school level.

1. Concept of radioactivity and characteristics
2. Types of radiation
3. How to detect radiation
4. Radioactive disintegration and decay
5. Half-life calculations
6. Biological effect of radiation and uses of radioisotopes
7. Nuclear energy – artificial transmutation
8. Binding energy
9. Nuclear fission and fusion
10. Uses of nuclear energy

Why students find nuclear chemistry difficult

In the course of the interview, participants were asked to explain why they find nuclear chemistry difficult to learn and to suggest ways by which the concept can be made easy to learn for chemistry students. Table 2 presents the participants' responses to these questions. The names presented in the table are not the real names of the participants.

Table 2**:** Interview responses of selected students

S/No	Pseudo name	Details of Student	Interview response	Suggestion for improvement
1	Lanre	Male; 16 years; SS3, private school	Because I found it difficult to differentiate between the rays like beta-rays and x-rays. Another reason I found it difficult is because of the half-life calculations. In-short, I don't understand the calculations at all.	I think my teacher too don't know it very well because there some topics he taught us and I understand them. Somebody who knows it very well should teach me.
2	Lade	Female; 16 years, SS3, private school	What I found difficult is how to write and balance the nuclear fission and fusion reactions. I also don't understand decay process very well how to write the equation.	I want my teacher to teach us again and very well with plenty examples.
3	Jaye	Male; 17 years; SS3; Private school	I did not enjoy the half-life calculations and how to balance the equations, I don't always get it right.	I think if I have another person taught the topic, I would know it more

S/No	Pseudo name	Details of Student	Interview response	Suggestion for improvement
4	Bola	Male; 16 years; SS3; public school	Our teacher did not explain it very well o. She just told us to go and form note on it and we were not given enough examples on the calculations.	We should be taught again with examples and get enough calculations.
5	Nuru	Male; 16 years old; SS3; public school	We were not taught very well, I don't understand the artificial radiation and because the calculation is not clear to me.	I want more explanation of the topic and the calculations.
6	Salami	Male; 15 years old; SS3; private school	I don't understand the half-life calculations and the process of decay.	Let my teacher teach us again and explain more on how to balance the equations
7	Ngozi	Female; 15 years old; SS3; private school	I think it is because there was no practical in the topic and half-life reaction is also not clear.	Let our maths teacher come and take the calculations.
8	Abubakar	Male; 17 years old; SS3; private school	The topic is difficult because I don't enjoy it. It has so many equations and reactions.	If I can have extra lesson on it, I will understand it well.
9	Benjamin	Male; 16 years old; SS3; private school	My teacher did not teach us the calculations but I try to learn with my friends and we are not still clear about it.	I just want someone to put me through the calculations and equations.
10	Tiwatope	Male; 17 years old; SS3; private school	The topic has many calculations and someone must cram so many definitions. I don't even like the topic sef.	May be our teacher should organise extra class for like the English teacher.

From the interview responses are two themes associated with students' difficulty in understanding nuclear chemistry. These themes are deduced by identifying the most common reason(s) for difficulty as expressed the participants.

Theme one: Difficulty with calculations in nuclear chemistry.
Theme two: Difficult with equation of reactions.

The reasons for these difficulties are not farfetched. For theme one, it has been observed that generally, most students have phobia for mathematics or learning activities involving calculations which is either due to poor background in mathematics, inability of the teacher to provide adequate explanation and examples or laziness and lack of concentration on the part of the students. For theme two, difficulty encountered can be associated with inadequate knowledge of the teacher in subject matter, inadequate use of examples and illustrations, lack of learning materials by the students, and lack of opportunity to learn after school.

Indigenous (cultural) knowledge related to the concept of nuclear chemistry as a difficult topic in senior school chemistry

Studies which revealed the potency and positive impact of Culturo-Techno-Contextual Approach (CTCA) on the academic achievements and attitude of students towards science (Adamu, 2019; Akintola, 2019; Egerue, 2019; Ogunbanwo, 2019**;** Okebukola et al., 2015; Saanu, 2015) are now piling at a very fast rate. It is based on these growing and evidence-based successes of CTCA that this study presents five indigenous knowledge cases that can be adapted to ease the difficulties experienced by African students in learning nuclear chemistry.

Case study 1: Binding energy is a major concept that learners must understand in nuclear chemistry. Culturally, this concept can be likened to plastering of building. After a house is molded using clay brick, our ancient fathers will then get plenty of faeces from goats or cattle, soak in water and mash together. Afterwards the mashed product is then used to rub the walls of the building as plaster. In the course of doing this, some of the mashed faeces been used for the plastering will fall off – loss of mass (known as mass defect in energy binding) while majority will bind with wall.

Case study 2: Half-life concept can be explained using the reduction is size that is seen in cutlasses.
Most times, unconsciously, we just observe that the farmers' cutlasses are losing weight. Though not specifically measured but it is in the belief of farmers that the reduced cutlass can still be used for a longer period than it has taken to get to its current state.

Case study 3:
It is cultural practice to use fire to break a substance into pieces. In those days, our forefathers use large amount of fire to break up rocks particularly if they are found in places considered to be of need. Bombarding the piece of rock with fire for a period long enough to crack the heavy substance and breaking it into lesser weight afford them the opportunity to push the piece of rock away and make good use of the space and sometimes the interest might even be to make use of the split rock. The process exemplifies the concept of nuclear fission.

Case study 4: Among the benefits of radioisotopes, is the use of radiation as insect and pest control. It is within the practice of Africans to control insect like sun-fly by setting up little fire usually by burning of woods or charcoal in the presence of certain leaves. As the leaf gets burnt, it radiates to the environment and such the environment becomes non-conducive for insects. If the energy released to the atmosphere by this process is not strong enough to kill the insects, it at least will drive them away for as long as the radiation persists.

Another cultural practice is the use of hot object for preventing or killing germs which can be likened to the use of radioisotope for sterilisation. Take a person with a wound. After a while of non or improper treatment, pain begins. When this situation arises, it is within our practice to put a metal object in fire, heat until it gets hot and technically place it on the surface of the wound to kill the germs which in turn reduce the pain and further quicken healing of the wound. In some cases, small amount of red oil is dropped on the metal and the hot oil is then spread on the surface of the wound. This case is commonly used to treat wounds with narrow surface area. For example, wound sustained by means of nail pecking.

Case study 5: Farmers make ridges for planting purposes. After a planting and harvest season, the farmer begins the planting exercise and new ridges would have to be made. It is a cultural practice of professional farmers not to merely adjust the exiting ridges but rather fuse the sides of two parallel ridges to make a new one in the middle – an existing space which was the walkway during planting session. This process can be used to explain nuclear fusion.

Theorising on the application of the Culturo-Techno-Contextual Approach on breaking barriers to learning of nuclear chemistry

The Culturo-Techno-Contextual Approach (CTCA) is a method of teaching and learning science invented by Peter A. Okebukola in 2015 to break the barriers to meaningful learning of science. Barriers such as fear of science due to its special language and mathematical orientation; deficit of facilities for teaching and learning; abstract nature of some of the concepts; and perception that science is only for the gifted are melted and broken down by CTCA.

The approach is an amalgam, drawing on the power of three frameworks- (a) cultural context in which all learners are immersed; (b) technology-mediation to which teachers and learners are increasingly dependent; and (c) locational context which is a unique identity of every school and which plays a strong role in the examples and local case studies for science lessons. The theory emphasises culture localisation as basis for understanding human behaviour and promoting learning (Okebukola, 2019).

Application of the CTC Approach

The procedure for implementing CTCA involves featuring the culture, technology and context frameworks in the delivery of every lesson. It follows a 5-step process (see www.ctcapproach.com). These are:

1. Inform students ahead of time of the topic to be learned in class. Ask each student to reflect on indigenous knowledge or cultural practices and beliefs associated with the topic or concept. Students should be made aware that such reflections are to be shared with others in class when the topic is to be taught.
2. At the start of the lesson and after the introduction by the teacher, students are grouped into mix-ability, mix-sex groups to share individual reflections on the indigenous

knowledge and cultural practices and beliefs associated with topic. All such reflections are documented and presented to the whole class by the group leaders. The teacher wraps up by sharing his/her indigenous knowledge and cultural practices associated with the topic.

3. The teacher progresses the lesson, drawing practical examples from the immediate surroundings of the school. Such examples can be physically observed by students to make science real. This is one of the "context" flavours of the approach.
4. As the lesson progresses, the class is reminded of the relevance of the indigenous knowledge and cultural practices documented by the groups for meaningful understanding of the concepts. If misconceptions are associated with cultural beliefs, they are cleared by the teacher.
5. At the close of the lesson, the teacher sends a maximum 320-character summary of the lesson (two pages) via SMS or WhatsApp to all students. After the first lesson, student group leaders are to send such messages. This is one of the technology flavours of the approach.

Summary, Conclusion and Recommendations

This study carefully highlighted the relevance and importance chemistry to humans from different perspectives. It emphasised the need to reduce or remove the difficulties that students encounter in learning chemistry which often arise from teaching in abstraction and inability of the teacher to provide local examples available within the immediate environment of the leaners and how this can easily be overcome by harnessing the power of indigenous knowledge with current classroom practices.

Through the use of the CTC approach, chemistry teachers can now relate classroom content with the indigenous knowledge of the learners, given them a sense of reality just as expressed in cases 1-5 and thereby reducing learning difficulty. Not only that, the CTC approach will equally help to develop the learners' social skills as they get to fetch information from parents and more knowledgeable individuals and also relate with classmates during group discussions. Most importantly, it will give the students some sense of pride knowing that Africa has a rich indigenous knowledge system before the adoption of the western culture which are useful and relevant even in this jet age.

In addition, the "techno" aspect of the CTC will attract the interest of the students to learning as it perfectly meets the needs and nature of the 21st century learners who are natives of the digital world by providing some level of pleasure through colourful electronic visuals and whatever pleases teaches effectively. To this end, chemistry teachers are enjoined to embark on a learning or information gathering process that equips them with the knowledge they need to help leaners draw conceptual understanding from cultural and indigenous knowledge system no matter how little related to classroom discussion. Chemistry teachers must realise that utilising the opportunities afforded by technology (such as audio-visual instructional aids) to support and enhance teaching delivery with the singular aim of melting learning difficulties in chemistry becomes non-optional.

Government and private school owners are equally enjoined to queue behind this platform by organising training and retraining workshops for chemistry teachers on acquisition, integration and utilisation of the CTC approach to promote meaningful learning. Identified individuals within the community who are rich in cultural knowledge can also be invited as resource persons to share their knowledge with the learners and teachers during class sessions under the approval of the school authority. If the Culturo-Techno-Contextual Approach (CTCA) is adopted and well utilised, it will not only help to break barriers to meaningful learning but serve as a means of preserving and promoting cultural knowledge and keeping history alive for generations to come.

References

Adam, U (2019). *Potency of culturo-techno-contextual approach on students' achievement in and attitude towards mutation and variation.* (Research report submitted in part fulfilment of the Bachelor of Science Education - Biology), Lagos State University, Nigeria.

Akani, O. (2015). Chemistry Education for Life and Service to Humanity: Panacea for Wealth Creation and National Development in Nigeria. *International Journal of Scientific and Allied Research, 1*(1), 1-7.

Akintola, A. (2019). *Impact of Culturo-Techno-Contextual (CTC) Approach on Students' Achievement on Perceived Difficult Topics in Biology*. (Unpublished research project report for the degree of Bachelor of Science Education), Lagos State University, Ojo, Lagos Nigeria.

Egerue, I. (2019). *Impact of sociocultural factors on scientific explanations in genetics and ecology offered by senior secondary students in Lagos State*. (Doctoral thesis in progress), Lagos State University, Nigeria.

Marker, S. C., Konkankit, C. C., Walsh, M. C., Lorey, D. R., & Wilson, J. J. (2019). Radioactive World: An Outreach Activity for Nuclear Chemistry. *Journal of Chemical Education*.

Matlin, S. A., Mehta, G., Hopf, H., & Krief, A. (2015). The role of chemistry in inventing a sustainable future. *Nature chemistry*, *7*(12), 941.

Mihindo, W. J., Wachanga, S. W., & Anditi, Z. O. (2017). Effects of Computer-Based Simulations Teaching Approach on Students' Achievement in the Learning of Chemistry among Secondary School Students in Nakuru Sub County, Kenya. *Journal of Education and Practice*, *8*(5), 65-75.

Ogunbanwo, G. (2019). *Relative effectiveness of the culturo-techno-contextual approach on students' performance in genetics and evolution*. (Unpublished research project report for the degree of Bachelor of Science Education). Lagos State University, Ojo, Lagos Nigeria.

Okebukola P.A. (2019). What is Culturo-Techno-Contextual Approach (CTCA). Retrieved from http://ctcapproach.com/index.php/about-ctca/

Okebukola, P.A.O., Ige, K, Oyeyemi, A. Olusesi, O., Owolabi, O, Okebukola, F, and Osun, G. (2016). *Exploring the Impact of Culturo-Techno-Contextual Approach (CTCA) in Tackling Under-Achievement in Difficult Concepts in Biology.* Proceedings of the 2016 Conference of the National Association of Research in Science Teaching (NARST), Baltimore, USA.

Özmen, H., DemİrcİoĞlu, G., & Coll, R. K. (2009). A comparative study of the effects of a concept mapping enhanced laboratory experience on Turkish high school students' understanding of acid-base chemistry. *International Journal of Science and Mathematics Education*, *7*(1), 1-24.

Ratamun, M. M., & Osman, K. (2018). The Effectiveness Comparison of Virtual Laboratory and Physical Laboratory in Nurturing Students' Attitude towards Chemistry. *Creative Education*, *9*(09), 1411.

Saanu, T. (2015). *Exploration of the effect of the culturo-techno-contextual approach on the achievement and attitude of students in logic gate*. (Unpublished M.Ed Project Report). Lagos State University, Lagos, Nigeria.