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A Survey of the Awareness and Practice of Systems Thinking Approach (Sta) Among Chemistry Teachers in Southwest Nigeria

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Abstract: *There are suggestions that Systems Thinking Approach (STA)-based learning could better students' appreciation of the subject, extend their knowledge of chemistry concepts and principles and engender global sustainability goals. However, it appears that STA is not visible in chemistry education in Nigeria. The purpose of this study was to determine chemistry teachers' level of awareness and practice of the Systems Thinking Approach (STA). Four research questions were raised and answered. A total of sixty (60) pre-service and in-service chemistry teachers were randomly sampled from public schools within and around Ibadan, Southwest Nigeria. Two adequately validated response instruments (Teachers' Awareness of Systems Thinking Approach (TASTA; (α=0.85) and Teachers' Practice of Systems Thinking Approach (TPSTA; (α=0.77) were administered to the teachers. The data collected were analyzed using descriptive and inferential statistics. Results showed that the levels of chemistry teachers' awareness and practice of the systems thinking approach are relatively high (normative mean: $\bar{x}$ = 52.11 and $\bar{x}$ = 37.2 respectively). Pre-service chemistry teachers had a higher level of awareness of STA than in-service chemistry teachers. However, the difference was not significant. Also, chemistry teachers below the age of 30 had significantly higher levels of awareness of STA than teachers who were above 50 years. STA is known and somewhat practiced among chemistry teachers in Ibadan, Oyo state. It is suggested that continuous training should be encouraged especially among in-service and older chemistry teachers for them to keep abreast with the trends in teaching and learning.*
Keywords: *Systems Thinking, Curriculum, Learning Approaches, Chemistry, Student-Centered Learning.*

Introduction

Chemistry is a branch of science that explains and investigates the nature of matter as well as its relationships and interaction with other matter. It can be viewed as a scientific endeavour that is supposed to equip learners with essential learning skills. In Nigerian secondary schools, it is often taught as a science subject in the senior classes. This prepares them for science-based disciplines in tertiary institutions and careers in the future. Shamsuddin et al. (2017) describe chemistry education as "the acquisition of knowledge or ideals relevant to chemistry". Generally, chemistry education involves the communication of knowledge on the components, properties, interactions and changes that matter undergoes. The place of chemistry education in any nation cannot be undermined. Therefore, functional chemistry education is required and teachers serve as tools for actualizing the goals of chemistry education.

In Nigeria, secondary school teachers still undergoing training at the colleges of education or the university are termed as Pre-service teachers while graduates who are currently teaching in schools are termed as In-service teachers. Oftentimes, calls have been made for updates on the teacher education curriculum as well as continued training for in-service teachers. Within and outside the field of chemistry education, the most crucial factor is the approach adopted in passing instruction. Historically speaking, various approaches to teaching and learning have been derived from established theories.

A teacher is better armed when he or she has ample knowledge of various teaching approaches/methods and seeks to adopt new and innovative ones. In the literature, there is an abundance of studies on approaches/methods adopted in teaching secondary school chemistry. Among them are student-centred, inductive, process, student motivation, and Socratic approaches (Avwiri, 2011). In another study, researchers investigated two constructivism approach-based strategies named 7E Learning Cycle Model and Case-Based Learning (Adesoji & Idika, 2015). Other approaches include Guided-Discovery, Student-Centered Demonstration and the Expository (Udo, 2015); Incorporating Error Analysis Approach (Achor & Kalu, 2014); mastery learning approach(Furo, 2014); Demonstration & Lecture (Omwirhiren & Ibrahim, 2016); Flipped classroom modules (Eichler & Peeples, 2016); Cooperative learning (Mihindo et al., 2017).

In the face of constant evolution and advancement in how researchers in chemistry education view teaching and learning, there seems to be no end to the emergence of suggestions about the use of contemporary approaches to teaching chemistry. Some scholars recently pointed out that chemistry has so far been taught from a reductionist perspective (Hiller Connell et al., 2012; Orgill et al., 2019) focusing on chemistry principles and concepts as a separate entity and often narrowing experiments and generalized outcomes. There is a notion that chemistry learning would be better appreciated if it is studied in other fields or disciplines (Hayes et al., 2020). This school of thought pushes forward the idea that chemistry should be learnt holistically as a component of a larger system; studying the interconnections between chemistry concepts and concepts in other disciplines. This is largely known as Systems Thinking Approach (STA).

Systems thinking is said to be a derivative of the general systems theory which was proposed by Von Bertalanf (1972) and used to explain sciences such as biology which requires integration in problem-solving as a central idea. With STA, the main goal is "to understand the whole and its many levels of interrelationship that characterize the parts of the system". The idea of systems thinking was simply described "as looking for and seeing that everything has an orderly pattern and works as a system" (Kriswandani et al., 2022). In the real sense, scholars assert that what scientists may identify as parts aren't parts in any way, but rather in-built patterns that are connected to other patterns or networks, "none of which are understandable without contextualization"(Hiller Connell et al., 2012). In other words, there is a call for learners to redirect their erstwhile focus from the parts to the whole.

York et al., (2019) describe Systems thinking as "a holistic approach for examining complex, real-world systems, in which the focus is not on the individual components of the system but on the dynamic interrelationships between the components and on the patterns and behaviours that emerge from those interrelationships". They opined that this approach has erstwhile been used in other fields such as engineering and business and physics but hardly in chemistry or chemistry education. It is believed that systems thinking allows an individual to view higher-level activities or phenomena which erstwhile could not be seen to rise from a simple sum of the constituent parts of a whole system (Orgill et al., 2019, Stavrianeas et al, 2022).

Mahaffy et al., (2018) aptly put this into perspective, arguing that chemistry processes also involve systems which are made up of interconnected components and they along with their parts interrelate with various other systems such as the immediate environment. Perhaps, the work of York et al (2019) warrants some scholarly attention. Based on their findings, they suggested that STA can be applied in chemistry education and added that science students needed to acquire systems thinking skills. The argument is that secondary school students need to see links between chemistry concepts and vital issues in life (Mahaffy et al., 2018).

On one hand, however, Schultz et al., (2019) and Hayes et al., (2020) submitted that secondary school students are commonly taught chemistry in a traditional reductionist way. Usually, students of chemistry are not groomed in systems thinking i.e. considering systems from a broader perspective (Constable et al., 2019). It has however, been reported that many chemistry educators/ teachers are not aware of STA (Mahaffy et al, 2018) and that most articles on STA focused on students' development rather than the teachers and their capabilities to engage in systems thinking (York et al, 2019).

In chemistry education, STA creates opportunities in learning for chemical content to context connection. This means that it provides an avenue where the learning focus is an extension of the context-based approach (Orgill et al, 2019, Hayes et al, 2020) Within the spheres of education, the adoption of the systems approach is believed to yield several benefits including fostering higher-order thinking skills (critical thinking), students' retention of content, problem-solving abilities, active participation, more conceptual and in-depth learning, questioning. It was also reported that students were able to make further connections between topics/content taught within and across fields (York et al, 2019). In making a case for the inclusion of STA in Biology Education, Glissen & Knippels (2020) stated that systems thinking is supposed to help students get more understanding of biological systems and enable them to solve complex problems. Others believed that it would be much easier for chemistry graduates to proffer solutions to current global issues (pollution, poverty, food storage, etc.) if they were better equipped with STA skills, possess an appreciation of the interconnectivity among systems in the earth and taught to deal with problems in a cross-disciplinary context (Orgill et al, 2019; Mahaffy et al, 2018; Constable et al., 2019).

It is evident that the prospects associated with the inclusion of STA in chemistry instruction abound and educators are currently examining the modalities for its implementation. However, it is not clear if this innovative approach is popular among chemistry teachers in Southwest, Nigeria. Perhaps, this may impede its eventual adoption in classrooms. Therefore, this study surveyed the awareness and practice of STA among chemistry teachers in Southwest Nigeria.

Research Questions

1. What is the level of chemistry teachers' awareness of STA?
2. What is the level of chemistry teachers' practice of STA?
3. What is the difference in the level of awareness of STA among pre-service and in-service chemistry teachers?
4. Does the level of chemistry teachers' awareness of STA differ, with respect to age?

Methods and Materials

The study used a descriptive survey method of research. No variable was manipulated. The population comprised chemistry teachers in Ibadan metropolis. Data was gathered by way of administering questionnaires to the sample respondents. The respondents of the study were sixty (60) chemistry teachers randomly selected from three local government areas within and around Ibadan. Two response instruments were developed and used for this study. The two instruments, Teachers' Awareness of Systems Thinking Approach (TASTA) and Teachers' Practice of Systems Thinking Approach (TPSTA) were adapted from the Teachers' Awareness and Practice of

Sustainable Development Scale used by Babalola (2019). Initially, TASTA contained 21 items while TPSTA contained 20 items. Necessary adjustments with respect to language use and context were made. The questionnaires were presented to experts in education for scrutiny and face validity. Consequently, all errors were removed. The instruments were then administered to 20 chemistry teachers who were not intended to be part of the main study. The internal consistency reliability statistics were used to analyse their responses for reliability using Cronbach's alpha. The items which were found to lack internal consistency (items with negative corrected-total correlation) were taken out. Finally, 17 and 14 items were found reliable for TASTA and TPSTA, respectively. The values obtained were TASTA (α=0.85) and TPSTA (α=0.77). After ensuring that all necessary authorizations were obtained, the instruments were administered to the teachers who were sampled for the study. A section of the questionnaire was used to obtain demographic data of the teachers. All the data gathered were analysed using descriptive statistics of frequency count, mean, percentages and standard deviation as well as Inferential statistics of T-test, ANOVA and Tukey's posthoc analysis. The normative mean was also used to determine if the teacher's awareness and practice level is low or high.

Results

Table 1. Demographic data of respondents

Title	Frequency (n)	Percentage (%)
Gender		
Male	23	38.3
Female	37	61.7
Age		
Under 30	39	65
30-50	14	23.3
Over 50	7	11.7
Highest Educational Qualification		
PhD	0	0
Masters	3	5.0
Bachelors	24	40.0
NCE	3	5.0
Pre-service	30	50.0

Research question 1: What is the level of chemistry teachers' awareness of the systems thinking approach?

Table 2: Chemistry teachers' awareness of the systems thinking approach

S/N	Statements	$\bar{X}$	SD
1	There are other approaches to teaching other than the conventional	3.60	0.68
2	I am aware of systems thinking as an approach to problem-solving	3.17	0.53
3	There is no systems thinking-based curriculum.	2.33	0.83
4	I am aware that chemistry processes include systems of interconnected components and these systems and their components interact with various other systems	3.39	0.50

5	I am aware that systems thinking is a new approach to teaching and learning	3.14	0.69
6	It is not possible to use the systems thinking approach in chemistry	2.87	0.57
7	I am aware that chemistry concepts should be learnt from a holistic perspective	2.87	0.68
8	Chemistry students don't have to develop systems thinking skills	2.90	0.89
9	I have been trained in the use of the systems thinking approach.	2.33	0.84
10	My school’s curriculum is designed to enable teachers to teach chemistry from a holistic perspective	2.53	0.78
11	The systems thinking approach cannot equip chemistry students to become resourceful future global citizens	3.10	0.61
12	I am aware that an initiative has been taken by my school authorities to create awareness of System Thinking.	2.00	0.80
13	My co-teachers are aware of the systems thinking approach	2.10	0.71
14	I am aware that in chemistry, systems are interconnected	3.17	0.53
15	Using a systems thinking approach to chemistry teaching and learning may not improve students' learning outcomes	3.10	0.61
16	I am aware that teaching and learning chemistry is best when related to other science and non-science subjects	3.13	0.73
17	A systems thinking approach to teaching and learning will facilitate students' understanding of non-science subjects	2.93	0.64
18	I am aware that attending a workshop, seminar, symposium or conference on systems thinking approach can enhance my knowledge of systems thinking	3.45	0.87
Weighted mean = 2.92			
Criterion mean = 2.50			

Table 2 shows that the highest weight of the instrument is 4 and the least is 1, which gives 2.50 as the criterion means. Results show that the weighted mean, 2.92 is above the criterion mean of 2.50. This implies that chemistry teachers agreed with the items raised to measure their awareness of the systems thinking approach. The results also show the cluster mean of 52.11 (addition of all the 18 items mean scores), which is higher than the normative mean of 45 (multiply the 18 items by 2.50). This implies that the chemistry teacher's level of awareness of the systems thinking approach is high. Therefore, one may assume that the chemistry teachers in Ibadan are likely to be favourably disposed to learning and adopting STA, especially for the number of benefits such as better perception and enhanced comprehension of chemistry concepts.

Research question 2: What is the level of chemistry teachers’ practice of STA?

Table 3. Chemistry teachers’ practice of systems thinking approach

S/N	Statements	$\bar{X}$	STD.D
1	Does your school's curriculum reflect a systems thinking approach	2.40	0.89
2	Do you teach chemistry with respect to recognizing interconnections between ideas and concepts?	3.43	0.57
3	Does your school head encourage teachers’ use of conceptual models?	2.70	0.88

4	Do the chemistry students in your school learn chemistry as a system which relates to other systems?	3.10	0.72
5	Does your school ensure that teachers employ a global-focused approach to teaching chemistry?	2.90	0.67
6	Does your school ensure that teachers employ systems thinking approach to teaching other science subjects?	2.23	1.07
7	Does your school ensure that teachers employ systems thinking approach to teaching non-science subjects?	2.30	1.15
8	Does your school authority emphasise the use of systems thinking-based activities in the classrooms?	2.07	1.08
9	Do your chemistry lesson plans promote learning concepts from a holistic perspective?	2.93	0.69
10	Do your lesson plans and notes enable your students to differentiate types of flows and variables?	3.17	0.60
11	Do the chemistry topics you teach direct learners to systems thinking?	2.76	0.91
12	Are your instructional and learning materials provide broad learning experiences, showing connections among concepts?	3.10	0.71
13	Are the books available in your school in line with the systems thinking approach?	1.93	1.08
14	Is your school planning to educate teachers on the use of a systems thinking approach?	2.00	1.15
Weighted mean = 2.64			
Standard mean = 2.50			

Table 3 shows that the highest weight of the instrument is 4 and the least is 1, which gives 2.50 as the criterion means. Results show that the weighted mean is 2.64, which is above the criterion mean of 2.50. This implies that chemistry teachers agreed with the items raised to measure their practices of systems thinking approach. The results further reveal the cluster mean of 37.2 (addition of all the 14 items mean scores), which is higher than the normative mean of 35 (multiplied by the 14 items by 2.50).

Research question 3: Is there a difference in the level of awareness of STA among pre-service and in-service chemistry teachers?

Table 4. The difference between pre-service and in-service chemistry teachers' awareness of STA

Variables	N	$\bar{X}$	SD	Df	t	p-value	Remark
Pre-service	30	53.43	4.07	58	1.215	0.229	Not significant
In-service	30	51.83	5.96				

Table 4 showed that the difference between in-service and pre-service chemistry teachers' awareness of the systems thinking approach was not significant ($t = 1.12$; $p>0.05$). Although pre-service chemistry teachers had slightly better awareness of the systems thinking approach than the in-service chemistry teachers, the difference in their mean scores was not significant.

Research question 4: Does chemistry teachers’ awareness of STA differ, with respect to age?

Table 5. The mean difference in chemistry teachers' awareness of STA with respect to age

Age	N	$\bar{X}$	SD
<30	39	53.62	4.97
30 – 50	14	52.00	5.51
>50	7	48.43	2.88

Table 5 revealed the mean magnitude of chemistry teachers' awareness of STA concerning age. It was observed that chemistry teachers under 30 years had the highest awareness of STA mean score (53.62), followed by chemistry teachers within 30-50 years and less than 50 years, respectively. To determine if the mean differences were significant, ANOVA was carried out and the result was presented in Table 6.

Table 6. The difference in chemistry teachers' awareness of systems thinking approach by age

Model	Sum of Squares	Df	Mean Square	F	Sig	Remark
Between Groups	166.988	2	83.494	3.446	0.039*	Sig.
Within Groups	1380.945	57	24.227			
Total	1547.933	59				

* denotes significance at $p<0.05$

Table 6 revealed that there was a significant difference in chemistry teachers' awareness of STA by age ($F_{(2; 57)} = 3.45$; $p>0.05$). This implies that age had a significant influence on chemistry teachers' awareness of STA. To find which group means are different from each other, Tukey's Honestly Significant Difference (HSD) post hoc test was carried and the result is presented in Table 7.

Table 7. Tukey's Honestly Significant Difference (HSD) multiple comparisons of awareness by age

(I) Age	(J) Age	Mean Difference (I-J)	Std. Error	Sig.
<30	30-50	1.61538	1.53353	.547
	>50	5.18681*	2.02045	.034
30-50	<30	-1.61538	1.53353	.547
	>50	3.57143	2.27849	.268
>50	<30	-5.18681*	2.02045	.034
	30-50	-3.57143	2.27849	.268

* denotes significant $p<0.05$

Table 7 depicted that there was no significant difference in the awareness of chemistry teachers who were under 30 and those within 30-50 years but a significant difference existed between chemistry teachers who were under 30 and those who are over 50 years in favour of chemistry teachers who were less than 30 years. The table further revealed that there was no significant difference in the awareness of chemistry teachers who are between 30-50 years and those over 50 years. This indicated that the chemistry teachers less than 30 years of age had better awareness than their counterparts who were 30 years and above when their awareness of STA is concerned.

Discussion of Findings

It was found that chemistry teachers' level of awareness of the systems thinking approach (STA) was significantly high. This implies that the chemistry teachers are in some ways, aware of STA. This, however, is in contrast to the submission of Mahaffy et al., (2018) and Constable et al., (2019) who observed that most students are generally, not trained to engage in systems thinking. Therefore, one may assume that the chemistry teachers in Ibadan are likely to be favourably disposed to learning and adopting STA, especially for the number of benefits such as better perception and enhanced comprehension of chemistry concepts. As Mahaffy et al. (2018) rightly mentioned that post-primary science students need to learn chemistry as a subject that connects with other fields and matters of life.

Similarly, teachers' level of practice of STA was found to be moderately high. This implies that the extent to which chemistry teachers displayed practices related to the systems thinking approach is considerable. Perhaps, there are elements of STA already practised by the teachers, unintentionally. This, then reflects the supposition that STA is not isolated or unconnected to pre-existing approaches. With the recent calls for teachers to consistently engage in professional development through seminars and workshops, perhaps, many have unknowingly learnt some details about STA. Also, in an attempt to enhance their pedagogical skills, chemistry teachers in this study may have acquired and displayed some STA practices. Here then lies the hope that integrating STA-based learning into chemistry education in Nigeria, may not be unfeasible.

Furthermore, this survey found that there was no significant difference in the level of awareness between pre-service teachers and in-service teachers. This implies that they are virtually on the same level of awareness with respect to the systems thinking approach (STA). It appears that none of the two groups is exposed to more information than the other, in terms of professional development in the use of innovative teaching approaches such as STA.

Finally, when age was considered, it was found that the teachers who were below 30 years had a significantly higher level of awareness of STA than those older than 50 years. This may not be unconnected to the notion that younger teachers are constantly seeking better and more innovative ways of carrying out their professional tasks and responsibilities. No doubt, this has been facilitated by the intensity with which communication technology has been embraced by the younger population. On the other hand, the older ones have perhaps stuck to their 'good old ways' of doing things. Hence, it is imperative to make conscious efforts to constantly educate and train chemistry teachers, across boards, in the use of contemporary approaches such as STA-based teaching and learning.

Conclusion

There is some evidence that chemistry teachers (pre-service and in-service) are aware of STA and seldom display practices related to STA. There are also indications that the younger teachers are more aware of STA than their older counterparts in Ibadan, Oyo state.

Recommendations

It is recommended that continuous training should be encouraged especially among in-service and older chemistry teachers for them to keep abreast with the trends in teaching and learning. Moreover, there is room for research on the prospects of designing, developing and implementing an STA-based curriculum for teaching chemistry in Nigeria.

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