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The Content Relationship between the Chemistry and Mathematics Curricula in the Nigerian Senior Secondary Schools

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Abstract: *This study examines on a content basis, relationships among the chemistry and mathematics curricula for senior secondary schools. Seventeen chemistry teachers who have been teaching chemistry examined the chemistry concepts that require mathematical process skills in the Nigeria Senior Secondary School Mathematics Curriculum. Pearson Product-Moment Correlation Coefficient indicates significant relationships between the students' performances in chemistry and mathematics in the senior secondary school certificate examination. Further analyses indicate a strong relationship between the students' performances in chemistry in the senior secondary school certificate examinations and their chemistry teachers' mathematical backgrounds. It was concluded that the senior secondary school mathematics curriculum is definitely beneficial for chemistry students.*
Keywords: *mathematics, chemistry, curriculum*

INTRODUCTION

Given the economic and political challenges of our times, students will need plenty of practice developing and fine-tuning their 21st-century skills to become better problem solvers and more creative innovators. Current research on 21st-century skills and skill acquisition is focusing on social and cross-cultural interaction, developing and piloting programs and curricula for students to develop leadership and responsibility skills, and the development of a body of research that can support the preliminary research that illustrates the impact of 21st-century learning skills on student achievement and workforce development.

Chemistry is one of the science subjects taught in the Senior Secondary Schools (SSS) . Its curriculum content has some abstract concepts central to learning other science subjects (Okafor, 2017). Some students view chemistry as being disconnected from the realities of life (Okafor, 2017; Bennett et al., 2007).

The critical role of chemistry in daily life, in industry and society is limitless. Many of our day-to-day activities revolve around chemistry. Chemistry is everywhere; chemistry is life; chemistry is the oracle of modern science. Despite the key role of chemistry as the central science that forms the basic foundation to many disciplines and in improving the quality of life, the performance of Nigerian secondary students in the subject has for many years remained a matter of serious concern. Students at all levels of chemistry show a lack of manipulative ability or knowledge (or both?) of the basic mathematics deemed essential for an understanding of many problems in chemistry. In the teaching/learning of chemistry, however, experience has shown that manipulation of figures and signs which are mathematically based constitutes the major problem

for learners. This fact is attested to by the constant comments of the chief examiner's reports with regard to the student's performances in the area of chemistry. Between the years 2017 and 2021, the comments of the chief examiners have been similar and run like:

"Candidates have once again failed to make use of basic principles of mathematics in a simple calculation. Teachers have important roles to play here in establishing their students' confidence in the area of chemical arithmetic (WAEC,2021;12)".

Paradoxically, chemistry without mathematics is incomplete because it is a vital link in chemistry. Mathematics, the language of science and technology, has a symbolic relationship with chemistry, and scientific literature cannot be written without numerals. Such problems span virtually the entire range of chemistry and are not restricted to those encountered by physical chemists. It is not entirely the student's fault according to Dence (1990) for his weakness in handling many of these mathematical ideas because little of the mathematics presented in the classroom is directed towards applications. Mathematics teachers have enough on their hands to just present the basic concepts of their subject. It is time to come to grips with the issue and do something about it. We can no longer afford to equate difficulty with worthiness. Having the reputation of being the most difficult subject in school no longer holds the connotation of being the most worthwhile. We either make it easier or water it down to lose its meaning.

Chemistry at the High school level according to Herron (2016) emphasizes the mastery of three objectives; 1) the student communicates effectively, 2) the student demonstrates working knowledge of mathematics and 3)the student applies his/her acquired knowledge to think and solve problems.

Chemistry is a natural and effective vehicle for teaching mathematics skills. It is the exact arithmetic of atoms that comprises the basis of modern chemical theory. In fact, science is not science until it is quantified. Chemical concepts, ideas and principles lend themselves to the teaching of thinking, problem-solving skills and mathematics. Herron (2016) observed that chemical concepts that lend themselves to mathematics skills are density concepts as a review of simple algebraic equations, chemical formulas and equations, the mole concept, conservation of mass and energy, and the behaviour of gases.

The absence of mathematics prerequisites for chemistry courses can mislead both students and teachers. Teachers commonly assume that they can teach the 'one or two skills that students need for a particular calculation. However, facility in mathematics is more than the ability to carry out a particular operation; it also depends on fluency in those operations. If students cannot quickly manipulate numbers, recognize computational errors and handle abstract reasoning, the need to learn chemistry and develop mathematical skills simultaneously may be overwhelming.

Many investigations at different times and places have carried out studies relating to the problems of teaching/learning chemistry in secondary schools.. Such studies have revealed that students have difficulties understanding some topics or concepts. Studies by Herron (2016), Ibole(2000), Dence (2018) and Adeyegbe (2000), showed that students have difficulties in understanding stoichiometry, chemical equations, electrochemistry, mole concept, gas laws, chemical equilibrium, organic chemistry and IUPAC nomenclature. These topics have a direct bearing to mathematical operations. Chemistry cannot be chemistry if it is not quantitatively treated. A chemical reaction, which is the basis of chemistry however simple or complex, can be subjected to quantitative calculus. A chemist is often interested in the quantity of its starting materials and the products formed at the end of the reactions. Furthermore, there are often temperature changes, differences in mass-volume as well as changes in energy in the course of

chemical reactions. The manipulations of figures and quantities arising from such reactions lead to worthwhile chemistry. The teachers themselves encounter problems with the students especially in those areas demanding mathematical processes due to lack of transfer of mathematical skills learned in mathematics class to chemistry, while many students struggle against the handicap of inadequate preparation in mathematics.

Mathematics is deductive science while chemistry is an inductive science, inferring that Chemistry is a science built upon the foundation of experiments and experimental observations into which mathematical structure must be correctly integrated. But those who study chemistry do it blindly, for they see chemistry and mathematics as different subjects.

Studies of the correlation between marks obtained by chemistry and mathematics students revealed that students with higher attainment in mathematics had the best chances of success in chemistry. One such studies was by Ezenwa (1985). Similar studies by Ibole (2000) revealed that 54% of chemistry questions in the senior secondary school certificate examination SSCE May/June and Nov/Dec involved in chemical arithmetic. Nine of the objective questions were mathematical, five questions that required chemical arithmetic were set in the essay, while question one of the practical chemistry required a good knowledge of mathematics. Ibole(2000) opined that a good pass in chemistry requires a good knowledge of chemistry arithmetic.

There is, therefore, the need to link the teaching of chemistry at the senior secondary school level with mathematics. Who then is to make the links? Is it the chemistry teachers whose mathematical background is not firm? Or the mathematicians who know nothing about chemistry? There could be few people who would happily volunteer to teach both mathematics and chemistry in our secondary schools. We would be deceiving ourselves if we think that only mathematicians can impact mathematical knowledge in our students. What really seemed disturbing to the researcher is how little or no attention has been directed towards the effective teaching of mathematics to our students so as to enhance the transfer of these mathematical skills to chemistry processes and concepts at the senior secondary school level.

Now that mathematical skills are steadily increasing in the field of physical science in general and in chemistry in particular, the researcher is of the view that mathematics has not been given the proper place it ought to in the teaching of senior secondary chemistry. Most of the topics students find difficulties in understanding are topics that involve the application of mathematics.

This study will seek to identify the chemical topics in the senior secondary school chemistry curriculum that require the mathematical skills of the chemistry teachers and also to explore the difficult topics in chemistry and find out if they have mathematical linkages. This study raised the following questions to guide it:-

1. What are the mathematics topics that knowledge is a prerequisite to the understanding of chemistry?
2. Do chemistry teachers have the mathematical background necessary for them to teach chemistry topics effectively,
3. What is the relationship between senior secondary school chemistry students' performances and mathematics?

Material and Method

The research adopted the descriptive correlational design to study the content relationships between chemistry and mathematics curricula in Nigerian Senior Secondary Schools. Plateau state senior secondary schools formed the population from which the study was carried out with particular reference to the schools in the Jos and Bukuru metropolis. There were fifteen senior

secondary schools in the Jos North Area Inspectorate of Education and seven in the Jos south area inspectorate (Bukuru Metropolis) of Education. Four schools were chosen from the Jos North area inspectorate Education. The schools were chosen from private-owned and government-owned. Out of the six senior secondary schools selected, two were private-owned and four were owned by the government. Some of the schools were boarding while others were mixed-sex schools. The instrument used for data collection in the study was the structured questionnaire. The chemistry curriculum for the senior secondary school approved by the federal Ministry of Education was used in designing the questionnaire. The chemistry curriculum was drawn from senior secondary one, two, and three curricula. The questionnaire contained thirty items from the senior secondary one, two and three. The thirty items with sub-topics enabled the respondents to pin the actual problem areas. The questionnaire was divided into three parts. Part one of the questionnaire asked for background information of the respondent which included:- their qualifications, years of teaching experience, subject taught and classes, and mathematical background. Their names and other pieces of information that could make them open up about their identity were avoided. The percentage passes of their students in the senior secondary school certificate Examinations (SSSCE) in chemistry and mathematics were also part of the information sought. The second part of the questionnaire consisted of the thirty items In the SSS chemistry curriculum from SS 1-SSIII from which the chemistry teachers were asked to tick those topics they thought needed mathematical background for their understanding. Part three of the questionnaire consisted of thirty mathematical processes and skills from the mathematical curriculum of the senior secondary school as approved by the Federal Ministry of Education. Chemistry teachers were asked to tick those processes and skills that cannot be divorced from in the teaching/learning of chemistry topics in part two of the questionnaire. The questionnaire was personally administered by the researcher to seventeen chemistry teachers to respond to and submit to the researcher on the spot.

To establish the content validity of the questionnaire items, three professors of chemistry, two of whom were professors of physical chemistry, and one of inorganic chemistry were given the questionnaire items to ascertain the adequacy and comprehensiveness of the items as well as clarity of expressions used. They guided the revision of the items of the questionnaire and subsequent editing of the items. To measure the reliability of the instrument, the test-retest method was used. The questionnaire items were administered to some selected 10 chemistry teachers who were not form part of the sample. The Pearson Product Moment Correlation Coefficient(r) was used and it gave a reliability index of 0.79.

Results.

Research Question One

What are the mathematics topics that knowledge is a prerequisite to the understanding of chemistry?

Table 1. Teachers' Rating of Mathematical Topics Required for the Understanding of Chemistry Topics.

Mathematical topics	Frequencies	Percentages	Remarks
Four basic operations on number	15	88.2	Highly required
Pattern in numbers	12	70.6	Highly required
Indices, logarithms and standard form	13	76.5	Highly required
Measurement and mensuration	10	58.8	Moderately required
Proportions, variations and rates of change	11	64.7	Moderately required
Algebraic equations and change of subjects	12	70.6	Highly required

Circles, circumference and tangents	4	23.5	Lowly required
Cartesian coordinates	6	35.3	Lowly required
Intuitive solid geometry	2	11.8	Lowly required
Linear and non-linear Graphs Equations of straight lines	10	58.8	Moderately required
Sines and cosine formula	10	58.8	Moderately required
Circular measures	1	5.9	Lowly required
Factors and multiples	1	5.9	Lowly required
Progression	16	94.1	Highly required
Binary numbers and operations	3	17.6	Lowly required
Linear and simultaneous linear Equations	7	41.2	Moderately required
Angles, bearings and drawings	8	47.1	Moderately required
Inequalities	3	17.6	Lowly required
Longitudes and latitudes	3	17.6	Lowly required
Statistics	2	11.8	Lowly required
Probability	9	52.9	Moderately required
Sets, theory and operations	9	52.9	Moderately required
Simple integration and Differentiation	1	5.9	Lowly required
Estimation and approximation of numbers	11	64.7	Moderately required
Areas and perimeters of plane shapes	16	94.1	Highly required
Use of four-figure table	3	17.6	Lowly required

Table 2 shows that chemistry teachers highly required four basic operations on number, pattern in numbers, Indices, logarithms and standard form, algebraic equations and change of subjects, progression, and areas and perimeters of plane shapes as a prerequisite for the knowledge of chemistry. They also moderately require measurement and mensuration, proportions, variations and rates of change, linear and non-linear graphs equations of straight lines, sines and cosine formula, angles, bearings and drawings, probability, sets, theory and operations, and estimation and approximation of numbers. However, circles, circumference and tangents, cartesian coordinates, intuitive solid geometry, circular measures, factors and multiples, binary numbers and operations, inequalities, longitudes and latitudes, statistics, simple integration and differentiation, and use of four-figure table were lowly required.

Research Question Two

Do chemistry teachers have the mathematical background necessary for them to teach chemistry topics effectively?

Table 3. Chemistry Teachers' Mathematical Background.

Credit hours of Mathematics taken	Percentages
1-2	17.6
3-4	35.3
5-6	35.3
7-above	11.8
Total	100%

At least 4 credit hours of mathematics courses are supposed to be taken by graduates of chemistry. This is to boost their mathematical proficiency to handle any mathematical skill that may be found in teaching or learning of chemistry. From Table 2, 52.9% of the chemistry teachers

did not have up to the credit hours minimum. However, 47.1% were having the requisite mathematical background necessary for them to teach chemistry topics effectively.

Research Question 3

What is the relationship between the senior secondary school chemistry students' performances in chemistry and mathematics?

Table 3: Pearson r of the relationship between the senior secondary school chemistry students' performances in chemistry and mathematics

Variables	N	Pearson r	p-value	Remark
Chemistry	17	0.79	0.000	Significant
Mathematics	17			

Table 3 shows a Pearson r value of 0.79 and a p-value of 0.000. This indicates that a high positive significant relationship exists between the senior secondary school chemistry students' performances in chemistry and mathematics. The r square value of 0.624 implies that performance in mathematics accounted for about 62.4% of the total variability in Chemistry.

Discussion of Findings

A number of conclusions emerged from the findings of this study. The first fifteen of the twenty-seven mathematical concepts, processes and skills seemed to be most important for the mastery of senior secondary school chemistry. These mathematical concepts, processes and skills include:- Four basic operations on numbers; Patterns in numbers; logarithms, indices and standard form; Measurement and mensuration; Variations and rates of change; Algebraic equations and change of subject formulae; Linear and non-linear graphs; Estimation and approximation of numbers; linear and simultaneous linear equation; Statistics; Probability; Simple integration and differentiation; and use four-figure tables. Apart from these fifteen concepts, processes and skills six others Longitudes and latitudes; Intuitive solid geometry; Angles, bearings and drawings; Circles and circular measures; Cartesian coordinates; sets, set theory and operation on sets; seemed to be of little application in the mastery of the chemistry contents at the senior secondary school level.

Four basic operations on numbers; patterns in numbers; Logarithms, indices and standard forms; Proportions, ratios and percentages; variations and rates of change; Algebraic equations and change of formulae; measurements and mensuration; and the use of four-figure tables had been identified as the mathematical concepts, processes and skills that that the mastering of any chemistry content would not be easy without the mastery. These mathematical concepts processes and skills were rated very high by the chemistry teachers in the sampled schools.

Out of the fifty-nine chemistry topics fifteen were found to be linearly correlated to the fifteen mathematical concepts processes and skills. That is, their understanding will not be easy without the mastery of these fifteen mathematical concepts, processes and skills. These chemistry sub-topics included- the structure of atoms and nucleus; Chemical formula and equations; relative molecular mass; Empirical molecular formulae; Gaseous state and gas laws, PH and relative acidity and alkalinity; Analysis of composition and structure of organic compounds; chemical stoichiometry; Electrochemistry; Acid based titrations and calculations; Chemical kinetics; waters, solution and solubility; Quantum mechanics; and nuclear chemistry and radioactivity. This was in agreement with the earlier work by Adeboye, (1986); Adeyebe, (2000); and Coulson (2015).

It was also found that students who performed very well in mathematics also performed very well in chemistry in the two senior secondary school certificate examinations (WAEC 2016 and

NECO 2016). Thus, good knowledge of mathematics was necessary for the understanding of most of the contents of chemistry.

Conclusions

Based on the findings of this study, the following conclusions are drawn:

There is a significant relationship between the chemistry and mathematics curricula of Nigerian senior secondary schools. There was a linear correlation between some topics in mathematics and chemistry in the senior secondary school curricula. A good knowledge of mathematics is required for the understanding of chemistry at the senior secondary school level of education. A good mathematical background by chemistry teachers is necessary for the effective teaching of topics in the senior secondary school chemistry curriculum.

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