PRE-REQUISITE CAPABILITIES OF A SENIOR SECONDARY SCHOOL STUDENT IN THE LEARNING OF VOLUMETRIC ANALYSIS: A TEST OF GAGNE'S THEORY

OLATUNBOSUN, S. M. (Ph.D)[1] & AYODELE, M. O. (Ph.D)[2]
Curriculum Studies Department,
Faculty of Education, Ekiti State University
Ado-Ekiti, Nigeria.
[1]E-mail: smolatfrank@gmail.com
[2]E-mail: goksmann@yahoo.com
[2]Phone No: +234-803-969-6806

Abstract
The study sought to identify the pre-requisite concepts needed for the acquisition of the terminal concept; volumetric analysis. Data were collected from six secondary schools in Ekiti State. Two schools were drawn from each of the three senatorial districts of the State. A total of sixty students in SS III whose average age was 17 years were involved. Data were collection through questionnaire. The findings show that the following concepts are among the necessary pre-requisites for the acquisition of the terminal concept; volumetric analysis in this order: Acids, bases and salts, Balancing of equations, Calculation involving masses, Concentrations in moles per /litre and Mathematical concepts. It was also found that the performance in any of the pre-requisite concepts is a function of that of the order. The study also revealed that, age influences the performance of students in the pre-requisite concepts. It is recommended that, chemistry teachers should endeavor to develop the sub-summing concepts through the use of advance organizers which can facilitate subsequent relevant learning. In addition, chemistry teachers should teach these concepts in order of increasing difficulty, taking cognizance of the students' age.

Introduction
As children grow, it is observed that they move through an invariant sequence of stages marked by their ability to perform different tasks and master progressively more abstract subject matter. Interferences about capabilities can be drawn only on the basis of performances of some specified tasks where individual growth is correlated with mastery of hierarchically-ordered concept material such as volumetric analysis. The stages of development of the child will be assumed to be similar with some such ordering of this material. However, this assumption is faulty because the ordering of subject matter provides very doubtful evidence about the order of child development, particularly when the higher order tasks within the subject field are constructed in such a way as to assume the presence of lower level tasks (Adesoji and Olatunbosun, 2000).

Gagne (1970) theorized that development is the sum total of learned experiences. He approached the problem of human learning and its contribution to development from the point of view of determining the pre-requisites for specific learning tasks. By pre-requisites, Gagne suggests that learning the concept of (volumetric analysis) must be preceded by learning of atoms, equations, concentrations, calculation involving masses, etc. Pre-requisites can be determined by identifying those learnt skills of lower position that make a positive transfer to connected ones of higher position. In the light of this, students who have mastered a higher-order task in a concept could be examined in order to ascertain if they have also mastered the necessary low-order precursors. For example, students who have mastered volumetric analysis as a concept could be examined to ascertain if they have also mastered balancing of equations, acids, bases and salts, concentrations, etc. Also, those students who have not mastered the low-level tasks could be studied to see if they can successfully handle the higher level one.

The growth of logic in all individuals is assumed to follow the pattern of the evolution of knowledge. It is upon this background that the investigators sought to identify the pre-requisite capabilities of a senior secondary school student in the learning of volumetric analysis.

Underlying Theoretical Framework

Gagne's hierarchical concepts in senior secondary school chemistry can be structured and sequenced according to various theories of learning. A basic problem in chemistry teaching however, is the search for an efficient and yet economic strategy of transmitting chemistry concepts. Gagne's theoretical formulations are attempts to identify aspects of learning and to match these with the intellectual demands of the individual. While development is subordinate to learning, Gagne's paradigm insists on identifying valid, ordered sequences of instruction (pre-requisites) that can facilitate the learning of intellectual skills. Gagne's introduces his theory thus: From where the student begins and where is he going? What are the specific pre-requisites for learning, and what will he be able to learn next?

From this introduction, Gagne's theory offers an opportunity for the chemistry teacher to diagnose students' limitations and strengths effectively, thus permitting more adequate individualization and personalization of chemistry instruction. Little wonder, Gagne (1977) defined curriculum as a sequence of content that is arranged in such a way that the learning of each unit may be accomplished as a single act, provided the capabilities described by specified prior units (in the sequence) have been mastered by the learners.

Gagne's theory also offers chemistry teachers the opportunity of developing and conceptualizing agreed upon chemistry goals and objectives in a reality-oriented and learner-centered way.
Jones and Russel (1979) put it thus: A sub-part of the paradigm also provides clues for the development of teaching techniques and strategies that will probabilistically influence the acquisition of skills, knowledge and attitudes. Also Strauss (1972) indicated that it is possible to find "key concepts" which are distinguished to epitomize common features of a larger number of particular ideals.

Statement of the Problem

The importance of Gagne's hierarchical theory in teaching and learning of science cannot be overemphasized. Since development is asserted to be the sum total of learned experiences, then, learning the lower-order tasks is likely to facilitate the acquisition of higher-order tasks. It is on this premise that the study attempts to identify the pre-requisite capabilities of senior secondary school students in the learning of volumetric analysis. Based on the above problem, the study sought to provide answers to the following questions.

(i) What are the sub-concepts to be mastered by senior secondary students to learn the concept of volumetric analysis?
(ii) What is the hierarchical order of the sub-concept leading to the mastery of volumetric analysis by senior secondary students?
(iii) Is learning of any of the sub-concept a function of the other?

Significance of the Study

The findings would enable the chemistry teachers in the senior secondary school to identify the pre-requisite capabilities of their students before instructing them on a high level task such as volumetric analysis. Not only this, the teachers would also endeavor to teach these pre-requisites in hierarchical order, starting from the simplest task to more complex task. Furthermore, the study would enable the curriculum planners and Chemistry teachers to recognize such factors as age (in terms of cognitive structures), social and economic background of the student as influencing what class a particular concept should be learnt by students in a senior secondary school. Kelly (1975) in his own

contribution illustrated the significance of developing a construction of relationship between various concepts and affirmed with all seriousness that exactness of understanding requires an order of concepts.

Greenstone and Laine (1970) examined some pre-requisite capabilities in learning titration which is a major part of volumetric analysis. These include acids, bases and salt neutralization process, atomic theory, mole concept and determination of percentage by weight of solute in solution. Others are balancing of equations and determining the concentration of a given solution. The key issues in Gagne's learning paradigm are: The identification of clearly stated objectives, Instructions are ordered hierarchically and Learning outcome evaluated in strict learning terminologies.

Gagne`s theory is one of programmed instruction in which a number of unique learning outcomes are identified These are cognitive strategies (including problem- solving), motor skill, verbal information, attitudes and four different kind intellectual skills (discriminations, concrete concepts, defined concepts and rules). Gagne`s theory cannot be applied equally to the learning of all concepts. Each discipline has its own structure and the higher the relationships among concepts in a particular discipline the more amenable the discipline is to Gagne's learning paradigm especially based studies designed to test Gagne's theory have typically used the following strategy:

(a). an examination [evaluation] of the presence or acquisition of certain higher order task so as to check if low order task [pre-requisite] have been acquired.

(b). an evaluation of subjects who have not acquired the low order tasks so as to ascertain their ability to profit from instruction in high order concepts.

Chemistry offers a 'fertile ground 'for the testing of Gagnean paradigm because most concept in chemistry are inherently related on the basis of this, the need to identify pre-requisite capabilities of secondary school chemistry students in selected concept in chemistry is justified and Gagne's theory provides a conceptual framework for such investigations.

Hypothesis

H_{O1}: The concept of volumetric analysis is acquired in the following hierarchy:

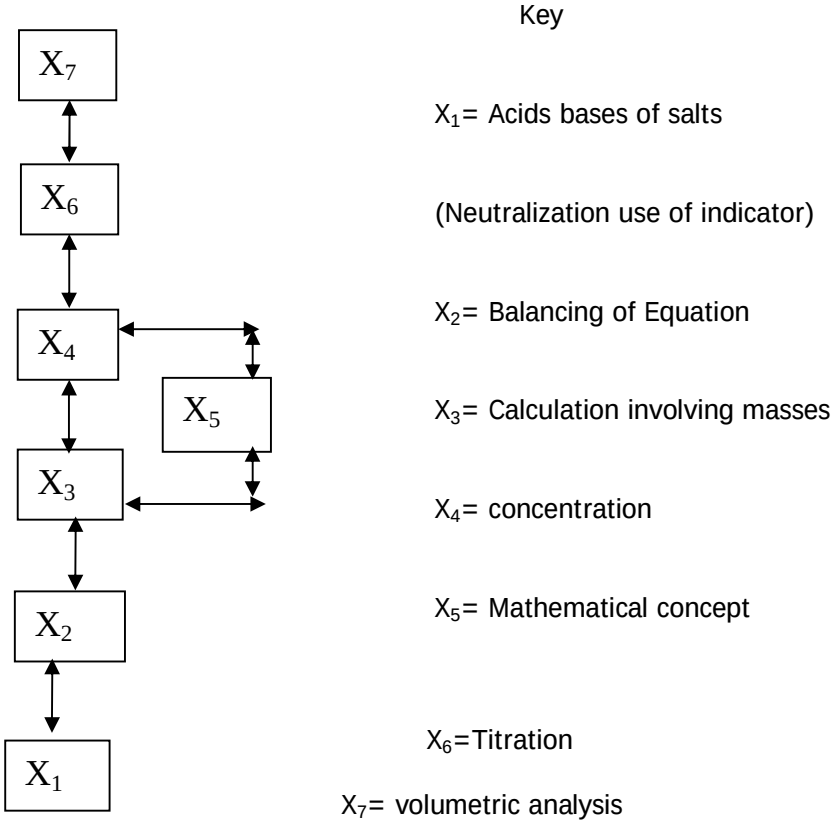

Fig 1: Hypothesized model showing the sequential order in which a senior secondary school student will learn volumetric analysis.

Methodology

The study is concerned with identifying the pre-requisite capabilities of senior secondary school III students in the learning of volumetric analysis as a test of Gagne's theory. The procedure is described under the different sections of the research method:

(i). Eligibility to participate in the study.
(ii). Sampling procedure and sample.
(iii). Instrumentation.
(iv). Data analysis and procedure.
(v). Data collection and scoring

To participate in the study a school must have completed the senior school 11 and carried out some practical works on volumetric analysis. Stratified purposive random sampling procedure was adopted in selecting six out of the eligible schools to ensure adequate representation of boys 'school, girls school and co-educational schools. In a selected school, simple random sampling was used to select one chemistry class to participate in the study. In a selected class, simple random sampling was also used to select 20 chemistry students to participate in the study. All the chemistry teachers in the participating class were automatically qualified to participate in the study.

Two instruments were constructed to collect the data used, these are, student-related and teacher-related instruments. The student-related instrument was Chemistry Achievement Test [CAT]. This instrument contained 20 items grouped into 5 objectives. Items 1 to 4 were grouped under acid, bases and salts. Items 5 to 7 came under equations while items 8 to 11 were based on calculation involving masses. Others were items 12 to 15 grouped under concentration and items 16 to 20 consist of mathematical concepts. The CAT (r = 0.81) was used to assess the level of acquisition of sub-concepts leading to the mastery of terminal concept of volumetric analysis. The teacher-related instrument used was Teacher Attitude towards Chemistry Practical and Problem solving Inventory (TATCPPI) (r = 0.86). The (TATCPPI) was constructed to measure disposition of chemistry teachers towards practical and problem solving. It contains two sections. A and B. Section A consists of items on personal information in which respondents were required to indicate their agreement or otherwise on a 4-piont scale of strongly Agree (SA), Agree (A) Disagree (D) and strongly Disagree (SA). The above instruments were used to collect the data for the study. The internal and external validity of the instruments was ensured by a team of experts' in the field of science education and in test and measurement. The administration and collection of all necessary information were done during the normal class hours. Correlational statistical procedure was used to analyze the data.

Data Analysis

Data were analyzed to identify the pre-requisite concepts for the acquisition of the terminal-concept, volumetric analysis, and the sequential order in which these capabilities are to be acquired.

Results

Question One

What is the sub-concept to be mastered by senior secondary students to learn the concept of volumetric analysis?

Table 1 presents the identified sub-concepts with the mean percentage score and difficulty index in each of the sub-concepts.

Table 1: Sub-concepts with the mean percentage and difficulty index of the sub-concepts

S/no	Sub-concept	Mean % score	Difficulty index	Remarks
1.	Acids, bases and salt	72.5	68.3	Easy
2.	Equations	49.4	48.5	Not so easy
3.	Calculation involving masses	32.8	32.9	Difficult
4.	Concentration in moles /litre	48.8	49.6	Not so easy
5.	Mathematical concepts	63.5	63.6	Easy

The above table reveals that 72.5% of the items in sub-concept 1 were answered correctly by the students. This implied that it is the easiest of the sub-concepts and should be learnt first before any of the listed 5 sub-concepts. Sub-concept 3 should be learnt last as only 32.8% of its items were answered correctly by the students. Also, the difficulty index follows the same order as the mean percentage increases.

Question Two

Is learning of any of the sub-concept a function of the understanding of the other?

Table 2: presents the relationship between sub-concepts 3 and 4 that is, calculation involving masses and concentrations.

This question was answered using the performances of 10 subjects selected randomly from the sample.

Students Performance (%) in Concept 3 X	Students Performance (%) in Concept 4 Y
26	33
40	48
40	42
59	61
55	58
52	62
60	68
48	54
34	60
∑X = 414	∑Y = 486
Rxy= 0.79	

The above table was analyzed using Pearson Product Moment Correlation Analysis Formula. The coefficient of correlation between sub-concepts 3 and 4 is 0.79. This shows that there is a high and positive relationship between the two concepts which implies that the learning of any of sub-concept 3 and 4 is a function of the understanding of the other.

Question Three What is the hierarchical order of the sub-concept leading to the mastery of the terminal concept-volumetric analysis by senior secondary school students?

Figure 2 presents the sequential order in which the concept, volumetric analysis could be learnt by senior secondary students.

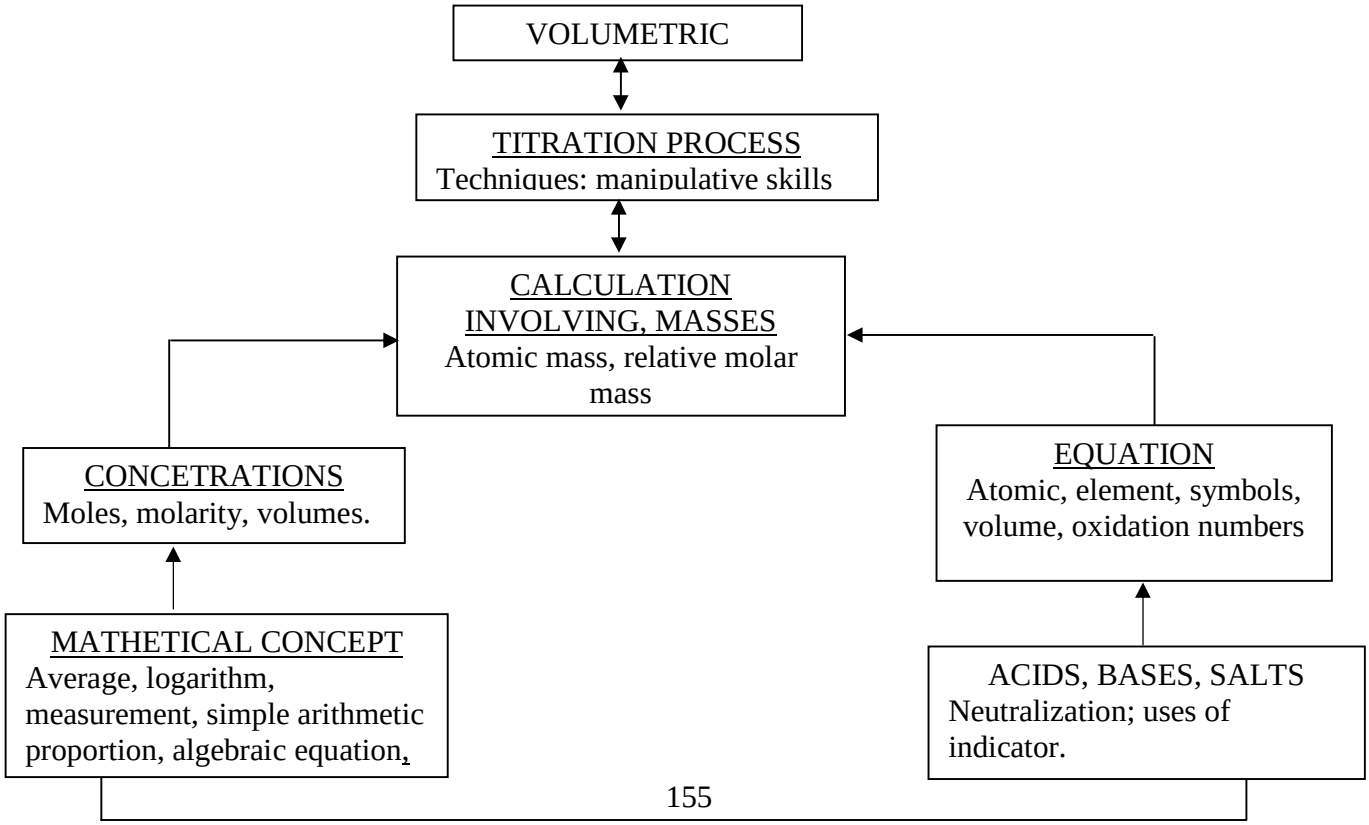

Fig II: A model showing the hierarchical order in which the concept volumetric analysis could learn by senior secondary students.

Discussion

The findings of the study revealed that the following sub-concepts are the necessary precursors to the learning of the terminal concept, volumetric analysis:

(i) Acids, bases and salts
(ii) Balancing of equation
(iii) Calculation involving masses
(iv) Concentration in moles per /litre
(v) Mathematical concept

It was also found that the easy learning of the sub-concept would be facilitated in the order shown in figure 2. Also the study showed that students' understanding of the pre-requisite concept influences the mastering of the other. This is evident in the correlation co-efficient obtained for concept 3 and 4 which is 0.79 (table 2 refers). Furthermore, it was discovered that most of the students performed poorly in the sub-concept 3 items which comprise of calculation involving masses. This could be accounted for by the age bracket of the participating students. This concept was introduced to students in SSI and most of them were not matured enough to master the concept because of its abstract nature.

Conclusion

The study has established that without mastering the above listed pre-requisite concepts, students in the senior secondary schools could not successfully learn the terminal concept, volumetric analysis. Also, these pre-requisite concepts have to be learnt in order of increasing difficulty vis-à-vis increasing cognitive development of the students. This is to say that the theory of learning hierarchies propounded by Gagne should be complemented with the Piaget's hierarchies of personality development in the learning of the concept-volumetric analysis. It is therefore, recommended that in the learning of volumetric analysis, senior secondary school students should possess the following pre-requisite capabilities:

(i) Acids, basses and salts
(ii) Mathematical concepts
(iii) Balancing of equations
(iv) Concentration in moles per/litre
(v) Calculation involving masses

The teachers of volumetric analysis should take cognizance of students' age before teaching any of the pre-requisite concepts. If and when possible, teachers should try and individualize their teaching because of differences in the periods in which students assume pre-operational and formal operational stages.

During the teaching of volumetric analysis, teachers should put into practice the Gagne's theory of learning hierarchies, Piaget hierarchies of personality development and even the conceptual hierarchies as proposed by Jessen, to achieve the desired goal. To cater for the manipulative skills, all necessary equipment and chemicals such as burettes, pipettes, acids, bases, indicators, etc should be put in place.

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