Prestige Journal of Education, Vol. 7, No. 2, December 2024 ISSN: 2645-324X (Print)
A publication of the Association for the Promotion of Innovation in Education (APIE) ISSN: 2645-3223 (Online)

Mathematics Ability Level and Students' Achievement in Chemistry Quantitative Problem-Solving in Senior Secondary Schools in Uyo Local Government Area, Nigeria

[1]**Iberedem Bassey Daniel, Ph. D**
ibedzman@yahoo.com
Department of Chemistry

[1]**Nsikan Edet Dan**
nsikand8@gmail.com
Department of Physics

[1]**Victor Akpaiya Udom**
udomvictor456@gmail.com
Department of Computer Science
[1]*College of Education*
Afaha Nsit, Akwa Ibom State

Abstract

The study investigated the effects of Mathematics ability level on students' achievement in chemistry quantitative problem-solving in Uyo Local Government Area of Akwa Ibom State. Two research questions and two hypotheses guided the study. The study adopted a true experimental pretest posttest research design. The study sample consisted of one hundred (100) SS2 Chemistry students in public co-educational secondary schools in the study area selected using simple random sampling technique. Two researchers-developed instruments, Mathematics Ability Test (MAT), designed to classify students into mathematics ability groups with reliability index of 0.88, and Achievement Test on Chemistry Quantitative Problems (ATCQP), designed to measure the students' achievements with a reliability index of 0.85, were used in gathering data for the study. The data obtained were analyzed using mean, standard deviation and Analysis of Covariance (ANCOVA). The results showed that students taught using problem-solving instructional strategy had the best achievement, students of high mathematics ability achieved significantly better than students of average and low mathematics ability in decreasing order. Consequently, it was recommended, among others, that students' *confidence in their mathematical insight and abilities should be developed and maintained.*

Keyword: mathematics ability, problem-solving, chemistry, achievement, quantitative

Introduction

Chemistry is an integral part of the academic curriculum in senior secondary schools. It is usually studied alongside other science related subjects such as Biology, Physics and Mathematics. Chemistry is a core subject in the study of many courses such as Medicine, Pharmacy, Biochemistry, Microbiology, Engineering and Agricultural Science. A sound knowledge of Chemistry is therefore of great importance to science students and the society at large. However, despite the relevance and usefulness of Chemistry, studies have shown that students' performance in Chemistry has been relatively low in contemporary times (Daniel, Etiubon et al., 2024). Considering the critical role of Chemistry in national development, it is needful to lay a solid foundation in students to enhance their academic achievement and proficiency.

One of the goals of chemistry education is to develop students' problem-solving skills in the subject. Such skills are to help students overcome difficulties in some concepts in the chemistry curriculum. However, due to the abstract, complex and conceptually demanding nature of chemistry, most secondary school students find a number of Chemistry concepts difficult to learn (Daniel & Ekanem, 2023). According to Daniel, Ekanem et al. (2024), these concepts mostly involve aspects of quantitative problems such as electrolysis, mass-volume relationships, solubility and calculations involving chemical equations. As noted by Shadreck and Chukunoye (2018), quantitative problems constitute a major impediment in chemistry courses, both at the secondary and tertiary levels of education. Okoh (2015) asserted that quantitative problems in Chemistry are multi-topic, complex and abstract in nature. They require students' deep problem-solving skills.

Problem-solving is an active pedagogy that links with other innovations which inherently supports a discovery-based approach to learning. Ndukwe (2021) and Udo (2015) described it as a cognitive learning strategy which is aimed at bridging the gap between conceptual understanding of the phenomena and the microscopic representation of the phenomena. According to Ndukwe and Mumumi (2019), problem-solving is an interactive classroom instruction that helps the students to work on difficult projects which they have no clue. It helps them to develop critical thinking skills which are beyond memorization of isolated facts and concepts. Daniel (2021) asserts that to be able to solve quantitative problems in chemistry, students should not only possess good mastery of

ISSN: 2645-324X (Print)
ISSN: 2645-3223 (Online)

quantitative concepts, but they should also possess mathematics ability to construct and balance chemical equations and also use them in calculation of quantities of chemical substances.

Mathematics ability is a human construct, which may be defined pragmatically or cognitively depending on the purpose of such definition. Pragmatic definitions are usually used when looking at this construct from a perspective of evaluation; for instance, when the focus is on identifying learners' potential or assessing learning outcome. From this perspective, mathematics ability can be defined as the ability to perform mathematical problems (Karsenty, 2014). It is the ability to understand and work with numbers and with ideas related to numbers. Cognitive definitions are used when relating to this construct from a theoretical perspective. Under this perspective, Mathematics ability can be defined as the ability to obtain, process and retain mathematical information (Vilkomir & O'Donoghus, 2009) or as the capacity to learn and master new mathematical ideas and skills (Daniel, 2021). This study considers mathematics ability from both pragmatic and cognitive perspectives.

The importance of mathematics ability in chemistry cannot be underestimated. Mathematics serves as a symbolic expression in Chemistry to show the structure of the relationships between different factors. Symbolic expressions allow learners to have a better understanding of chemistry contents and improve their procedural knowledge of inter-relating various symbols when solving problems in chemistry (Daniel, 2021). Without some mathematical skills, calculations in Chemistry are made extremely difficult. A careful study of the Senior Secondary School Chemistry Curriculum in Nigeria and the West African Senior School Certificate Examination syllabus reveals that a proper understanding of mathematical concepts in Chemistry requires a good knowledge of basic mathematics and generally involves a lot of computation which makes mathematics an important aspect of it. Udousoro (2011) observed that the understanding of mathematical concepts improves problem-solving abilities and develops a healthier attitude towards chemistry. As such, it is imperative that enhanced achievement in quantitative chemistry would be fostered by a good background knowledge of mathematics.

Mathematics has generally been accepted as the bedrock of science and technology and it is a very important subject in the secondary school curriculum. Also, mathematics is considered as a service tool for the study of sciences. But despite its importance and usefulness, mathematics is a subject that is most feared by students at primary, secondary and even in the tertiary levels of education (Obafemi & Ogunkule, 2014; Charles-Ogan & Okey, 2017). Hence, students with poor mathematics knowledge cannot solve quantitative problems in chemistry. According to Nzoloman (2013), the choice of science subjects in Nigerian schools is much dependent on the learner's ability in mathematics, because proficiency in mathematics is of basic importance to the study of science. Charles-Ogan and Okey (2017) asserted that mathematics knowledge is the language of science and it gives form and definiteness to the properties of quantitative interpretations of ideas and imaginations. Mathematics pervades chemistry so much that its impact and influence can be felt in every part of it.

The effectiveness in students' understanding and application of concepts in chemistry can be guaranteed through adequate possession of mathematical skills. Hence, students' understanding of the basic mathematical concepts are of great importance. According to Charles-Ogan et al. (2017), the achievement in sciences is often contingent upon mathematical knowledge and there exists an impregnable link between mathematics and chemistry. Daniel (2021), in explaining why mathematics form the basis for the study of chemistry, maintains that mathematics is necessary in enabling chemistry students to draw useful conclusions about composition, yielding and energy balance in reacting systems and other chemistry concepts that require computation and calculations. However, studies on mathematics ability as it affects students' academic achievement are inconsistent. Findings by Ibrahim (2011) showed that mathematics ability had no significant influence on students' performance in chemistry. Other research reports from different dimensions, (Udousoro, 2011; Charles-Ogan et al., 2017; Daniel, 2021) found positive significant relationship between mathematics ability and students' achievement in chemistry.

Statement of the problem

Despite the relevance and usefulness of chemistry in national development, studies have shown that students' performance in chemistry has been relatively low in contemporary times. These performances often generate much concern among the stakeholders in the education sectors. In a situation where the students are blamed for poor performance, emphasis is only placed on the students' cognitive or intellectual ability. Little or no attention is given to the fact that students' mathematical ability can affect their academic achievement in chemistry. Based on the above assertion, the problem of this study is to determine the relationship between mathematics ability and students' academic achievement in chemistry quantitative problem-solving. How effective is mathematical ability in enhancing students' achievement in chemistry quantitative problem-solving? This study, therefore sought for plausible answers to this question.

ISSN: 2645-324X (Print)
ISSN: 2645-3223 (Online)

Research questions

The following research questions guided the study:

1) What are the students' achievement mean scores in chemistry quantitative problems when taught using problem-solving teaching strategy and expository teaching strategy?

2) What are the achievement mean scores of students of different mathematics ability levels (low, average and high) in chemistry quantitative problem-solving when taught using problem-solving teaching strategy and expository teaching strategy?

Hypotheses

The following null hypotheses were formulated for testing at .05 alpha level:

Ho1: There is no significant difference in the achievement mean scores of students in chemistry quantitative problem-solving when taught using problem-solving teaching strategy and expository teaching strategy.

Ho2: Students with different mathematics ability level (low, average and high) do not differ significantly in their achievement mean scores in chemistry quantitative problem-solving when taught using problem-solving teaching strategy and expository teaching strategy.

Methodology

The study adopted a true experimental pretest and posttest design. This composed of two randomly assigned groups (experimental and control). The population of the study consisted of all the 2,129 Senior Secondary II Chemistry students in all the 14 public Secondary Schools in Uyo Local Government Area of Akwa Ibom State in 2022/2023 school year. The sample consisted of one hundred (100) SSII Chemistry students from two selected schools in the area. Simple random sampling technique was used in selecting the two schools in the area. The students were randomly assigned to the groups. Both schools had fifty (50) chemistry students.

Two researchers-developed instruments, Mathematics Ability Test (MAT) and Achievement Test on Chemistry Quantitative Problems (ATCQP), were used in gathering data for the study. MAT is a 30-item 4-option multiple choice test that was designed to measure the mathematics ability level of the students. The items were drawn from basic concepts in mathematics relevant to chemistry quantitative problem-solving. ATCQP is a 40-item 4-option multiple choice test designed to measure the achievement of students in solving quantitative problems in Electrolysis in Chemistry. The instruments were face and content validated by three independent assessors: two content experts in chemistry education and one measurement and evaluation expert. Test-retest reliability strategy was adopted to generate data to establish the reliability of the instruments. The data generated were analyzed using Pearson Product Moment Correlation (PPMC). The analysis yielded a reliability coefficient of 0.88 and 0.85 for MAT and ATCQP respectively.

Mathematics Ability Test (MAT) was administered to all the students in order to classify them into high, average and low mathematics ability groups. Each correct answer on Mathematics Ability Test (MAT) was scored 1mark and incorrect answer was scored zero. This gave a maximum score of 30 marks and a minimum score of zero. The scores were ranked to determine the mathematics ability levels of Chemistry students. Students whose scores ranged from 21-30 were regarded as being of high mathematics ability, those whose scores were ranged between 11-20 were regarded as being of average mathematics ability and those whose scores were below 11 were regarded as being of low mathematics ability. The Achievement Test on Chemistry Quantitative Problems (ATCQP) was also administered to the treatment and control groups as pre-test. Thereafter the lesson notes prepared by the researchers were used in teaching the concepts of Electrolysis in the two groups for two weeks. The students in the experimental group were taught using problem-solving instructional strategy while those in the control group were taught using the conventional expository teaching strategy. At the end of the treatment, the reshuffled version of the ATCQP was administered to all the students as posttest. The data obtained were analyzed using mean and standard deviation in answering the research questions, while analysis of covariance (ANCOVA) was used in testing the null hypotheses.

Presentation of results

Research question 1: What are the students' achievement mean scores in chemistry quantitative problems when taught using problem-solving teaching strategy and expository teaching strategy?

Table 1: Mean and standard deviation of students' pre-test and post-test scores classified by treatment groups

Treatment Group	N	Pretest		Posttest		Mean
		Mean	SD	Mean	SD	Difference
Experimental Group	50	7.24	3.21	38.42	6.72	31.18
Control Group	50	8.18	4.30	20.72	4.16	12.54

ISSN: 2645-324X (Print)
ISSN: 2645-3223 (Online)

Results in Table 1 show that the pre-test and post-test means scores with standard deviation scores for the experimental group (problem-solving instructional strategy) are 7.24, 38.42, 3.21 and 6.72 respectively. However, the pre-test and post-test mean scores with standard deviation scores for the control group (expository teaching method) are 8.18, 20.72, 4.30 and 8.16 respectively. Table 1 also shows that the mean difference of the experimental group is 31.18 against the mean difference of 12.54 of the control group indicating the superiority of the problem-solving instructional strategy group over the expository teaching strategy group in chemistry quantitative problem-solving.

Ho1: There is no significant difference in the achievement mean scores of students in chemistry quantitative problem-solving when taught using problem-solving teaching strategy and expository teaching strategy.

Table 2: Analysis of Covariance (ANCOVA) of students' post-test scores classified by treatment group with pre-test scores as covariates

Corrected Model	**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected model	1631.679[a]	2	815.839	14.808	.000	.431
Intercept	8470.967	1	8470.967	153.754	.000	.501
Pre-test	3.223	1	3.223	0.59	.890	.481
Treatment	1267.531	1	1267.537	23.007	.000	.389
Error	4805.127	95	50.580	-	-	-
Total	211554.000	100	-	-	-	-
Corrected Total	6536.072	99	-	-	-	-

a. R Squared = .755 (Adjusted R Squared = .734)

In table 2, the calculated F-ratio for the effect of treatment at df 1,95 is 23.007, while its corresponding calculated level of significance is .000 alpha. This level of significance is less than .05 in which the decision is based, indicating that there was a significant difference in the achievement of students taught using problem-solving instructional strategy and expository teaching method. With this observation, the null hypotheses one was rejected. This means that there is a significant difference between the achievement mean scores of students in chemistry quantitative problem-solving when taught using problem-solving instructional strategy and expository teaching strategy.

Research question 2: What are the achievement mean scores of students of different mathematics ability levels (low, average and high) in chemistry quantitative problem-solving when taught using problem-solving teaching strategy and expository teaching strategy?

Table 3: Mean and standard deviation of students' pre-test and post-test scores classified by treatment groups and mathematics ability

Treatment Group	Mathematics Ability	N	Pretest		Posttest		Mean Difference
			Mean	SD	Mean	SD	
Experimental Group	High	11	8.11	3.81	44.21	3.64	36.10
	Average	23	4.30	4.20	32.80	3.84	28.50
	Low	16	2.84	3.89	24.41	3.60	21.57
Control Group	High	17	8.04	4.28	30.74	4.11	22.70
	Average	19	6.48	3.87	17.92	3.94	11.44
	low	14	2.71	4.01	13.39	3.80	10.68

Table 3 shows the pre-test and post-test mean scores, and standard deviation sores of high, average and low Mathematics ability students in the experimental and control groups. Results in Table 3 also show that high mathematics ability student in the experimental group had the highest mean gain score (36.10) followed by their average mathematics ability counterparts in the same group (28.50). This was followed by high mathematics ability students in the control group (22.70), followed by low mathematics ability students in the experimental group (21.57), followed by average mathematics ability students in the control group (11.44) followed by low mathematics ability students in the control group (10.68), in decreasing rank order. Also, the scattering of the raw scores about the post-test mean was widest among the high mathematics ability level students in the control group. Whether the difference between the mean scores of the group by mathematics ability was statistically significant was assessed by testing of hypotheses two.

Ho2: Students with different mathematics ability level (low, average and high) do not differ significantly in their achievement mean scores in chemistry quantitative problem-solving when taught using problem-solving teaching strategy and expository teaching strategy.

ISSN: 2645-324X (Print)
ISSN: 2645-3223 (Online)

Table 4: Analysis of Covariance (ANCOVA) of students' post-test scores classified by treatment group and mathematics ability levels with pre-test scores as covariates

Source	**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected model	1901.472[a]	2	950.736	17.373	.000	.461
Intercept	10644.643	1	10644.643	213.162	.000	.514
Pre-test	4.062	1	4.062	.123	.721	.424
Treatment	1279.870	1	1279.870	23.388	.000	.394
Mathematics Ability	3281.721	2	1640.530	49.985	.000	.406
Error	5281.721	95	55.589	-	-	-
Total	245154.000	100	-	-	-	-
Corrected Total	6536.072	99	-	-	-	-

a. R Squared = .704 (Adjusted R Squared = .692)

In Table 4, the calculated F-ratio for the mean effect of treatment at df 1,95 is 23.388, while its corresponding calculated level of significance is .000. This level of significance is less than .05 alpha in which the decision is based; indicating that there was a significant difference between the academic achievement of students in the concept taught given the teaching methods used. Table 4 also shows that the calculated F-ratio value for the main effects of mathematics ability at df 2,95 was 49.485 while its level of significance is .000. This level of significance is less than .05 alpha in which the decision is based, indicating that the influence of mathematics ability on the students' achievement was statistically significant. With this observation null hypotheses two was rejected. The direction of significance was determined using Scheffe post hoc test in Table 5.

Table 5: Scheffe PostHoc homogeneous subset for post-test scores of the students classified by mathematic ability groups

Mathematics Ability	N	Subset 1	Subset 2	Subset 3
Low	30	14.90	-	-
Average	42	-	24.45	-
High	28	-	-	33.86
Sig.		1.000	1.000	1.000

The group mean scores in the homogeneous subset in Table 5 show that students of high mathematics ability achieved significantly better than those in average and low ability in decreasing order, while students of average mathematics ability achieved significantly better than those of low mathematics ability level in the treatment groups.

Discussion of the findings

The findings with regards to the effects of problem-solving instructional strategy and students' academic achievement in chemistry quantitative problem-solving show that there was a significant difference in the students' academic achievement. Students thought using problem solving instructional strategy performed significantly better than students taught using the conventional expository teaching strategy. This implies that problem-solving instructional strategy is more effective in enhancing students' achievement in chemistry quantitative problem solving. This finding is in line with the findings of Udo (2015), Ndukwe and Mumuni (2019), and Ndukwe (2021) who observed that problem solving instructional strategy is more effective and a reliable method of teaching than the conventional exposition teaching method. The better enhancing effect of problem-solving instructional strategy could be attributed to the fact that it helps students to develop critical thinking skills which is beyond memorization of isolated fact and concept.

As regards the influence of students' mathematics ability given the instructional strategies used, the findings indicated that its influence on students' achievements was statistically significant. Students with high mathematics ability achieved significantly better than those with average and low ability in decreasing order; while students with average mathematics ability achieved significantly better than those of low mathematics ability level in both the experimental and control groups. This observation agrees with the findings of Nzoloman (2013) and Charles-Ogan et al. (2017) and Daniel (2021) that there is a positive significant relationship between mathematics ability and students' achievement in chemistry. This is because there is a correlation between mathematics and problem-solving abilities. The findings also agree with Charles-Ogan and Okey (2015) and Obafemi and Ogunkule (2014) that students with poor mathematics knowledge cannot solve mathematical problems in science. This implies that without mathematics, subjects like chemistry and other science related subjects would vaguely be understood, analyzed and evaluated. Conversely, the findings disagree with Udo (2011) and Ibrahim (2011) who reported that mathematics ability level had no significant influence on students' achievement in chemistry.

ISSN: 2645-324X (Print)
ISSN: 2645-3223 (Online)

Conclusion

Based on the findings of the study, it was concluded that problem-solving instructional strategy is an effective instructional strategy for promoting the ability of students in solving problems in science. Also, adequate mathematics ability is required for solving quantitative problems in science. Hence, effort has to be made in order to improve students' acquisition of mathematics skills, if a positive learning outcome is expected in chemistry and other science subjects.

Recommendations

The following recommendations were made based on the findings of the study:

1) Students' confidence in their mathematical insight and abilities should be developed and maintained.
2) Science students should be exposed to the basic mathematics principles, laws and theories, especially as needed in quantitative problem-solving.
3) Students-centred interactive structure instructional strategies such as problem-solving instructional strategies should be used in teaching quantitative problem solving in chemistry and other related science subjects.
4) Individual differences in students' ability, background and attitude should be taken into consideration by teachers and parents.

References

Charles-Ogan, G. I., Arokoyu, A. A. & Amadi, J. C. (2017). Effects of Mathematics Knowledge on Chemistry Students' Academic Performance in Gas Law. *European Journal of Mathematics and Computer Science,* 4(1), 1-6.

Charles-Ogan, G. L. & Okey, I. F. (2017). Effects of Mathematic Knowledge on Physics Students Performance in Electromagnetism. *International Journal of Theoretical and Mathematical Physics,* 7(4), 61-67.

Daniel, I. B. (2021). *Effects of Problem-solving Models on Students' Achievement and Retention of Chemistry Quantitative Problems in Senior Secondary Schools in Uyo, Nigeria* [Unpublished Ph. D Thesis]. University of Uyo, Uyo.

Daniel, I. B. & Ekanem, N. U. (2023). Effects of Problem-solving Models on Students' Achievement in Quantitative Chemistry Problem-solving in Senior Secondary Schools in Uyo, Nigeria. *Prestige Journal of Education,* 6 (2), 31 – 42.

Daniel, I. B., Etiubon, R. U., Ekanem, N. U. (2024). Comparative Effects of two Problem-solving Models on Chemistry Students' Achievement in Mass Volume Relationship in Secondary Schools. *African Journal of Science, Technology and Mathematics Education (AJSTME),* 10(2), 238-244.

Daniel, I. B., Ekanem, N. U. & Nelson, I. A. (2024). Effects of Search-Solve-Create-Share and Algorithm Problem-Solving Models on Students' Performance in Chemistry Quantitative Problems in Senior Secondary Schools in Uyo, Nigeria. *Journal of Education,* 13(1), 255-264.

Ibrahim, M. A. (2011). *Effects of Problem-solving Models on Students Achievement and Retention in Redox Reactions in Senior Secondary Schools in Kano, Nigeria* [Unpublished Ph. D Thesis]. Bayero University Kano, Kano.

Karsenty, R. (2014). Mathematics Ability. In: S. Lerman (Ed.), *Encyclopedia of Mathematics Education*. Dordrecht: Springer.

Ndukwe, R. C. (2021). Effects of Problem-solving Strategy on Chemistry Students' Performance in Secondary Schools in Abia State. *International Journal of Humanities, Social Sciences and Education,* 8(7), 226-232.

Ndukwe, R. C. & Mumuni, A. A. (2019). Effects of Instructional Strategies on Chemistry Students Retention in Secondary Schools in Osisioma Local Government Area, Abia State. *British International Journal of Education and Social Sciences,* 6(7), 45-53.

Nzoloman, O. N. (2013). Relationship between Mathematical Ability and Achievement among female Secondary School Students in Bayelsa State, Nigeria. *Procedia-social and Behavioural Sciences,* 106(12), 2230-2240.

Obafemi, D. T. & Ogunkule, R. A. (2014). Mathematics Ability of Secondary School Physics Students and Performance in Sound Waves. *International Journal of Research and Development,* 1(11), 111-123.

Okoh, E. A. (2015). *Effect of three Problem-solving Models on Students' Performance and Attitude to Chemistry Quantitative Problems in Senior Secondary Schools* [Unpublished Ph.D Thesis]. University of Uyo, Uyo.

Shadreck, M. & Chukunoye, O. (2018). Comparative Effects of two Problems-solving Instructional Strategies on Students' Achievement in Stoichiometry. *Journal of Mathematics, Signs and Technology Education,* 14(2), 1-9.

Udo, M. E. (2015). Effects of Problem-solving, Guided Discovery and Expository Teaching Strategies on Students' Performance in Redox Reactions. *African Research Review,* 5(4), 231 – 241.

Udousoro, U. J. (2011). Effects of Gender and Mathematics Ability on Academic Performance of Students in Chemistry. *African Research Reviews,* 5(4), 201-213.

Vilkomir, T. & O'Donoghue, J. (2009). Using Components of Mathematical Ability for Initial Development and Identification of Mathematically Promising Students. *International Journal of Mathematics Education Science and Technology,* 40(2),183-199.