



Enhancing Secondary School Students' Achievement of Chemical Bonding Concepts in Chemistry Using Selvaratnam-Frazer and Polya's Problem-solving Models

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Abstract

This study investigated the effects of Selvaratnam-Frazer and Polya's Problem-solving Models on secondary school students' achievement in chemical bonding. The design of the study was a quasi-experimental research design with a population of 2500 SS1 Chemistry students in public schools. The sample comprised of 165 SS I Chemistry students from four intact classes selected by sample random sampling technique. The instrument used for data collection was Chemistry Achievement Test (CAT) with reliability index of 0.78 using Pearson Product Moment Correction. The data obtained was analysed using descriptive statistics and Analysis of Covariance (ANCOVA). The result showed that there was no significant difference in the academic achievement of students taught using Selvaratnam-Frazer and Polya's Problem-solving Models. There was also no significant influence of gender on students' academic achievement. It was recommended among others that Chemistry teachers should make effective use of Selvaratnam-Frazer and Polya's Problem-solving Models for teaching.

Keywords: Academic achievement, Gender, Polya's Problem-solving Model and Selvaratnam-Frazer Model

Introduction

Science is a vital effort on which nations rely on to make technological advancement. It is defined as the step-to-step study of nature acquired through the use of scientific method (Nwuba, Egwu, Awosika, Osuafor, 2023). According to Christian-Ike et al., (2024) science has been acknowledged as an instrument applicable to life and society as its applications to every aspect of life extending from agriculture, health, bioengineering, technology, communication and transportation has made it a necessary tool for national development. At the secondary school level, science is fragmented down and taught as basic subjects such as biology, chemistry and physics.

Chemistry is a science that systematically studies the composition, properties and activities of organic and inorganic substances and the various elementary forms of matter. Chemistry, by its nature, is

the central science because diverse subjects share essential links with it. It is one of the core subjects offered in Senior Secondary Schools. The understanding of chemistry is essential for effective study in many careers. As a building block for a range of science disciplines, it has the potential to link other sciences together and to foster greater scientific literacy (Tera, 2018). The teaching of Chemistry should develop in the students manipulative and experimental skills to make them competent and confident in conducting experiments.

In some countries, many students, from the secondary school to the university, struggle to understand Chemistry, and many do not succeed (Reid, 2018). Research has revealed that many students do not properly understand vital concepts in Chemistry due to its abstract nature (Adkins, 2020). Also, many of the

scientifically incorrect ideas held by the students go unchanged from their early years of schooling to the university and sometimes beyond (Wood & Donnelly-Hermosillo, 2019). Many high school and university students have problem understanding the more advanced concepts that are built upon the fundamental concepts of Chemistry and consequently experience difficulties with these ideas. This is because they do not fully and appropriately understand the fundamental concepts such as chemical bonding (Carson and Watson, 2022).

Chemical bonding is one of the most fundamentals of Chemistry. It explains other concepts such as molecules and reactions. Chemical bonding is the physical process responsible for the interactions between atoms and molecules and that which confers stability to bounded particles. Without it, scientists will not be able to explain why atoms are attracted to one another or how products are formed after a chemical reaction has taken place. Chemical bonding is a complex aspect of Chemistry. Not surprisingly, therefore, students find it difficult to understand or learn. Students' poor Problem-solving ability, learning difficulties and misconceptions in chemical bonding is an indication of the likelihood of a deficiency in instructional strategies used in the Chemistry classroom (Gongden, 2016). Science teachers and cognitive scholars both agree that efforts to comprehend and advance science and concepts in Chemistry should be focused on using appropriate teaching strategies.

Teaching strategies refer to the techniques of transmitting facts, skills, information and knowledge by the teacher to the learners so as to engage them in meaningful learning to achieve the objectives of the lesson (Joe, 2022). Ajoma (2019) sees teaching strategies as the professional techniques teachers adopt regularly in instructional exercises to enable them to impart relevant knowledge and skills to the learners. Eden, Tofi, Umoetuk and Akpan (2023) observed that teachers need to learn how to use teaching methods that encourage scientific processes and other desirable scientific approaches by adopting teaching methods which encourage Problem-solving strategies. There are various strategies available to a trained teacher to enhance the delivery of knowledge and skills to the learners. The various strategies have different effects on the academic achievement of the students. These include the Problem-solving models, the cooperative learning models, the inquiry learning models, the discovery learning models and the collaborative models, among others.

Problem-solving models are those strategies that outlines logical steps that, when followed, can produce an optimal solution to given problems. Eden *et al.*, (2023) describe problem –solving as student-centered teaching strategy where the student has the chance to recognize the problem, perform research, and find answers by learning how to solve real life problems. Margaret (2015) believed that problem-solving skills help students apply principles to scenarios found in the real world which can lead to an increase in their creativity and in turn would enhance their academic achievement. There are variants of Problem-solving models. These include Greeno Problem-solving; Selvaratnam-Frazer Problem-solving model; the Systematic Approach Problem-solving; Search, Solve, Create and Share (SSCS) Problem-solving model; and Polya's Problem-solving model. However, the problem-solving models of concern to this study are Selvaratnam - Frazer and Polya's Problem-solving models.

The framework for Selvaratnam-Frazer Problem-solving model (Selvaratnam *et al.*, 1982) has five stages which are: clarifying and defining the problem; selecting the basic relationship; deriving the relationship for the solution of the problem or calculation; gathering data; checking the units and elucidating the problem and finally revising, checking through steps 1-4, confirming the units and learning from the situation. Daniel and Ekanem (2023) in a study on the effects of Ashmore, Casey and Frazer: Selvaratnam-Frazer; and Search, Solve, Create, Share Problem-solving Models on students' academic achievement in quantitative problems showed that students taught using Selvaratnam-Frazer Problem-solving Model had the best achievement. Mandina and Ochonogor (2018) investigated the effects of Selvaratnam and Fraser and Ashmore *et al.* (1979) problem-solving instructional strategies on advanced level students' achievement in stoichiometry indicated a statistically significant difference.

Polya's Problem-solving model on the other hand, is a one that takes students through a systematic process of acquiring knowledge with the prompting of the teacher. It is a framework of four-step process: understanding the problem; devising a plan; carrying out the plan and looking back. These steps are explained further:

- i. Understanding the problem (recognizing what is asked for) by asking oneself, 'What am I looking for?' or "What information is given in the problem?"

- ii. Devising a plan for solving the problem (responding to what is asked for), asking oneself, “Do I know a similar problem?”, “Can I restate the problem?”
- iii. Carrying out the problem (developing the result of the response)
- iv. Looking back (checking, what does the result tell me?).

In a study by Eden *et al.*, (2023) on the effect of polya and target-task problem-solving teaching strategies on students’ achievement in electrolysis in Uruan Local Government Area of Akwa Ibom State found that there was a significant difference in the achievement mean scores of students taught polya and target-task problem-solving strategies. Olatide, Omosewo and Nwankwoet (2015) on effect of polya problem-solving model on senior secondary school students’ performance in current electricity showed that students exposed to polya problem-solving model performed better than those exposed to lecture method.

Gender difference is another factor commonly associated with students’ academic achievements. In the context of this study, the term is an analytic concept that describes sociological roles, cultural responsibilities and expectations of men and women in a given society or cultural setting. Eden and Mbuk (2019) defines gender as a word used to describe a person either as a man/boy or a woman/girl, adding that gender is an important factor that contributes to academic achievement in Chemistry. Some studies report significant influence of gender on the achievement of students while other studies indicate no significant influence of gender on achievement of students (Daniel, 2021; Daniel and Ekanem, 2023; Eden *et al.*, 2023; Eden, Akpan Noah, 2023). This has underscored the need of the present study to find out if there is any significant influence of gender on Chemistry students taught chemical bonding using Selvaratnam-Frazer Problem-solving Model and Polya's problem-solving model.

Research Questions

The following questions guided the study:

1. What is the difference in the academic achievement mean scores of students when taught chemical bonding using Selvaratnam - Frazer Problem-solving Model and when taught using the Polya's Problem-solving Model?
2. What is the influence of gender on academic achievement mean scores of students taught

chemical bonding using Selvaratnam - Frazer Problem-solving Model compared with those taught using Polya's Problem-solving Model?

Research Hypotheses

The following null hypotheses were formulated to guide the researchers:

- Ho₁:** There is no significant difference in the academic achievement mean scores of students taught chemical bonding using Selvaratnam - Frazer Problem-Solving Model and those taught using the Polya's Problem-Solving Model.
- Ho₂:** There is no significant influence of gender on the academic achievement of students’ taught chemical bonding using Selvaratnam-Frazer Problem-Solving Model and Polya's Problem-Solving Model.

Research Method

A quasi-experimental design was used with a 2 x 2 factorial arrangement in a non-randomized pre-test, post-test setting. The population of the study consisted of all SSI chemistry students in all public coeducational secondary schools in Uyo Local Government Area. According to figures released by the State Secondary Education Board, Uyo, there were 2,500 students offering Chemistry in the 13 public secondary schools in the area during the 2020/2021 academic session. Simple random sampling technique was used to select four schools from the population and assigned experimental group 1 and 2. The sample consisted of 165 (84 and 81 for experimental groups 1 and 2 respectively) Chemistry students from four intact science classes. The instrument used for gathering data for the study was a researcher- developed 20- item 4-option multiple-choice (A-D) test and tagged: Chemistry Achievement Test (CAT). The instrument was face validated by an experienced Chemistry teacher and two lecturers in science education and in the field of Measurement and Evaluation, University of Uyo. The validators were required to check for the appropriateness of the items in terms of the language used, content coverage and class level. The researchers were appropriately guided, with all comments and suggestion in-cooperated in the final form of the instrument. The content validity of the CAT was ensured using the test blue print designed by Bloom Taxonomy (knowledge, comprehension, application, analysis, synthesis and evaluation). The reliability of the Chemistry Achievement Test (CAT) was

determined using test-retest method. The trial-test sample of 30 Senior Secondary students was used; and the second test was administered two weeks after the first. The data obtained was analysed using Pearson Product Moment Correlation (PPMC) coefficient, r . The results showed a reliability index of .78. This result indicated that the instrument was reliable. The researchers visited the schools selected and sought for permission from the authorities of the schools to use their schools and students for the study. The cooperation of the subject teachers was also solicited and obtained for a smooth conduct of the study. To ensure that the subject teachers qualified as research assistants, one week was used to brief them on the modalities of the research. Mock drills were done to

minimize the errors due to teacher variables. Thereafter, the research assistants administered the Chemistry Achievement Test (CAT) to all the treatment groups as pre-test after the drills. This was followed by teaching the concepts to both treatment groups by the research assistants. The students in the Experimental group 1 were taught using Selvaratnam-Frazer Problem-solving Model; those in Experimental group 2 were taught using Polya's Problem-solving Model. After the treatment, the reshuffled version of CAT was administered on the two groups as post-test. The data obtained were analysed using mean and standard deviation to answer the research questions while Analysis of Covariance (ANCOVA) was used in testing the null hypotheses at .05 level of significance.

Results

Table 1: Mean (\bar{x}) and standard deviation of students' achievement mean scores

Treatment Groups	N	Pre-test		Post-test		Mean Gain Score
		\bar{x}	Sd	\bar{x}	Sd	
Selvaratnam-Frazer	84	24.98	5.31	59.55	8.13	34.57
Polya	81	25.23	6.93	58.86	8.67	33.63

Table 1, shows the pre-test and post-test mean scores and standard deviation of scores of the two groups of students taught using Selvaratnam-Frazer, and Polya's problem solving models. The pre-test mean scores of the students in the Selvaratnam-Frazer, and Polya's problem solving groups displayed are 24.98 and 25.23, respectively, and their standard deviation scores are 5.31 and 6.93, respectively. The post-test mean

scores are 59.55 and 58.86 for Selvaratnam-Frazer, and Polya's problem solving groups, respectively, while their standard deviation scores are 8.13 and 8.67, respectively. The post-test - pre-test mean scores differences of 34.57 and 33.63 respectively, for those in Selvaratnam-Frazer and Polya's groups. This observations show that those taught using Selvaratnam-Frazer model had a better mean gain score.

Table 2: Summary of Analysis of Covariance (ANCOVA) of the students' post-test scores classified by treatment groups with pre-test score as covariate

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Decision at $p < .05$ alpha
Corrected Model	1202.67	2	601.33	9.44	.000	S
Intercept	45624.63	1	45624.63	716.55	.000	S
Pretest	1183.41	1	1183.41	18.59	.000	S
Treatment	13.41	1	13.410	.21	.647	ns
Error	10314.91	162	63.67	-	-	-
Total	590020.00	165	-	-	-	-
Corrected Total	11517.58	164	-	-	-	-

In Table 2, the calculated F-ratio for the effect of instructional strategies at df 1, 162 is .21, while its corresponding calculated level of significance is .647

alpha. This level of significance is greater than .05 in which the decision is based; indicating that there was no significant difference in the academic achievement of

students in the concepts taught using Selvaratnam-Frazer and Polya's Problem-Solving Models. Thus the null hypothesis was retained.

Table 3: Mean and standard deviation of the influence of gender on students' mean scores when taught using Selvaratnam-Frazer and Polya problem-solving models

Treatment Groups	Gender	N	Pre-test		Post-test		Mean Gain Score
			\bar{x}	Sd	\bar{x}	Sd	
Problem-solving Models	Male	89	27.26	5.46	59.33	5.51	32.07
	Female	76	25.13	5.84	59.49	6.55	34.33

Table 3, shows the pre-test and post-test mean scores; and standard deviation of the influence of gender on students' mean scores using Selvaratnam-Frazer and Polya's Problem-Solving instructional models. The pre-test mean scores of male and female displayed is 27.26 and 25.13 respectively with standard deviation scores

of 5.46 and 5.84 respectively. The post-test mean scores of 59.33 and 59.49 for male and female students, respectively, with standard deviation scores are 5.51 and 6.55 respectively. The mean gain scores for male and female students are 32.07 and 34.33 respectively.

Table 4: Summary of Analysis of Covariance (ANCOVA) of gender on students' post-test scores classified by treatment groups with pre-test as covariate

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Decision at $p < .05$ alpha
Corrected Model	5597.37 ^a	4	1399.342	37.82	.000	S
Intercept	31965.66	1	31965.66	863.91	.000	S
Pre-test	66.02	1	66.02	1.78	.184	S
Treatment	1.88	1	1.88	.05	.822	ns
Gender	3.47	1	3.47	.09	.760	ns
Treatment * Gender	4385.65	1	4385.65	118.53	.000	S
Error	5920.21	160	37.00	-	-	-
Total	590020.00	165	-	-	-	-
Corrected Total	11517.58	164	-	-	-	-

In Table 4, the calculated F-ratio for the main influence of gender on the students' achievement at df 1,160 is .09, while its corresponding calculated level of significance is .760 alpha. This level of significance is greater than .05 in which the decision is based; indicating that there was no statistically significant influence of gender on students' mean achievement scores taught given the instructional models. Therefore, the null hypothesis was retained.

Discussion of Findings

The findings with regard to the effects of Selvaratnam-Frazer and Polya's Problem-solving

Models on students' achievement in chemical bonding showed that there was no significant difference in the academic achievement of the students. In other words, the achievements of the students were comparable. This indicates that both Selvaratnam-Frazer and Polya's Problem-solving Models are similarly effective in facilitating students' achievement in the concept area. This can be attributed to the fact that both problem-solving models are comparable as they enabled the students to follow a systematic process to solve problems. They provided a supportive framework for problem solving. Both models helped students to improve their critical thinking and analytical skills;

enhanced their ability to break down complex problems into manageable steps. Students are able to manoeuvre the learning task and create their own knowledge which in turn helped them to understand the concept of chemical bonding.

The findings of this study is in contrast with that of Daniel (2021) who found that students taught using Selvaratnam-Frazer Problem-solving Model had the best achievement. The findings of this study is also in contrast with that of Mandina and Ochonogor (2018) which found that there was a statistically significant difference between those taught using Ashmore *et al.* (1979) Problem-solving instructional strategy and Selvaratnam-Frazer Problem-solving model. These findings also contradict the findings of Eden *et al.*, (2023) which showed that there was a significant difference in the achievement mean scores of students taught polya and target-task problem-solving strategies.

Findings on difference between the academic achievement mean scores of male and female Chemistry students taught chemical bonding using Selvaratnam - Frazer Problem-solving Model compared with those taught using Polya's Problem-solving Model showed that there was no statistically significant difference between the academic achievement of male and female students in the concepts taught. This can be attributed to the fact that gender is not a determining factor in problem-solving ability; both models are effective for both males and females; there was equal access to learning opportunities; the instructional strategies used in both models are gender neutral. These findings support the idea of equity in education where both males and females have equal opportunities to learn and achieve academic success. The findings of this study is in line with Daniel (2021); Daniel and Ekanem (2023); Eden *et al.*, (2023) which showed that there was no significant influence of gender on the students' academic achievement in science.

Conclusion

The study concludes that students' achievement is similar when taught using either Selvaratnam-Frazer or Polya's Problem-solving models. There is no significant influence of gender on students' achievement. Therefore, both models are effective in promoting problem solving skills and learning outcome.

Recommendations

Based on the findings and the conclusions reached, the following recommendations are made:

1. Chemistry teachers should adopt either the Selvaratnam-Frazer or Polya's Problem-solving Models into the teaching practice to enhance students learning outcomes.
2. Curriculum developers should ensure the incorporation of both Selvaratnam-Frazer and Polya's Problem-solving Models into the curriculum to provide students with a structured approach to problem-solving.
3. Government, in conjunction with professional bodies such as STAN, should organize and sponsor regular workshops to train science teachers on the use of problem-solving models in teaching science concepts.

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