COMPARATIVE EFFECT OF TWO PROBLEM-SOLVING INSTRUCTIONAL STRATEGIES ON STUDENTS' ACHIEVEMENT IN STOICHIOMETRY

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ABSTRACT

The study aimed to investigate the comparative effects of Selvaratnam-Fraser and Ashmore et al Problem-Solving instructional strategies on Advanced Level students' achievement in Stoichiometry. The population of the study was drawn from 15 high schools in Gweru urban District of the Midlands province in Zimbabwe. Using convenience sampling techniques 8 high schools with n=525 Advanced Level Chemistry learners and 8 teachers participated in the study. Four schools formed the experimental group (n=250) and the other four schools formed the control group (n=275). The study employed a quasi-experimental design with a non-equivalent control group approach consisting of pre-and post-test measures. Intact classes participated in the study as it was not possible to randomly select participants for the study. The principal instruments for data collection were standardized achievement Tests in stoichiometry that were aligned to the Zimbabwe Schools Examinations Council A' level National syllabus for chemistry. The tests were written by all participants at pre- and post-stages of the experiment. The problem-solving instruction was implemented in four experimental schools by the respective chemistry teachers who had been trained as research assistants in the use of the problem-solving strategies in chemistry teaching. The four control schools were also taught by their teachers using the conventional lecture method. Analysis of Covariance (ANCOVA) was used to analyze data. The results of this study indicated that the participants in experimental schools performed significantly better than participants in control schools on certain aspects of problem-solving performance. The Scheffe's post- hoc test indicated that students taught using the Ashmore et al problem-solving instructional strategy performed better than those taught with the Selvaratnam-Fraser problem-solving strategy. Chemistry teachers are therefore strongly recommended to use problem-solving instructional strategies in their classes to facilitate students' problem-solving performance. The study further recommends that pre-service chemistry teachers be properly trained in instruction that promotes problem-solving and how to effectively implement problem-solving instruction. Furthermore, in-service training for practicing chemistry teachers is recommended so that they can embrace the skills of the problem-solving strategies for effective implementation of the strategies in teaching chemistry. *[African Journal of Chemical Education—AJCE 8(2), July 2018]*

INTRODUCTION

The critical role that science plays in the technological development of a nation cannot be overemphasized [1]. Recognizing this instrumental role that science plays in improving the socio-economic wellbeing as well as industrialization of nations it becomes important that science educators develop strategies of improving and promoting the teaching and learning of science [2]. Chemistry is one of the science subjects that plays an important role in national development. As noted by [3] the scientific development of any nation hinges upon the quality of chemical education offered in schools. Chemistry as a school subject is relevant to number of manufacturing industries such as pharmaceuticals, food processing, agricultural, clothing and textiles, petrochemical as well as metallurgical industries [1].

However, due to its abstract, complex and conceptually demanding nature, chemistry has been found to be difficult for most secondary school students [4, 5, 6, 7]. According to [8], chemistry students find a number of concepts difficult to learn. Stoichiometry has been identified as one of the topics in chemistry that students find difficult to learn [9, 10]. Research has shown that the poor performance by Zimbabwean students in chemistry is as a result of their poor problem-solving in stoichiometry [11]. The Zimbabwe Schools Examinations Council [12] chemistry examiners report notes the difficulties chemistry students have in performing numerical calculations involving the mole concept as well as writing of balanced equations.

Chemical stoichiometry has been found to be multi-topic, complex and abstract in nature as a result students find it difficult to comprehend [13]. [14] further note that stoichiometry is fundamental to all aspects of chemistry and requires students' deep problem-solving skills. To be able to solve stoichiometric problems, students should not only possess good mastery of stoichiometry concepts, but also ability to construct and balance reaction equations and using them in calculation of the quantity of chemical substances [14]. Furthermore, in stoichiometry, students are actively engaged in solving problems that are sophisticated [13]. To be actively engaged in solving sophisticated problems, students need to have knowledge structures that are well organized [15] which in most instances is lacking among high school students consequently they find stoichiometric problem-solving difficult to undertake. This lack of well-organized knowledge structures requires that chemistry educators intervene with different teaching and learning strategies to address students' problem-solving challenges and improve their capabilities in problem-solving.

Efforts to develop instructional strategies to enhance student's problem-solving abilities in chemistry have led to the development of many problem-solving models and has seen the establishment of these models in teaching and learning basic science [16, 17]. This has resulted in the enhancement of the academic achievement of students. In the Zimbabwean context, no research has attempted to study how problem-solving instructional strategies can enhance the abilities of chemistry learners in problem-solving. This study, therefore, seeks to investigate how selected problem-solving models [18, 19] can facilitate Zimbabwean Advanced Level chemistry students' problem-solving skills in stoichiometry.

STATEMENT OF THE PROBLEM

Students' poor problem solving ability, learning difficulties and misconceptions in stoichiometry is an indication of the likelihood of a deficiency in instructional strategies used in the chemistry classroom a conclusion drawn by [1]. Chemistry educators should therefore find strategies of learning difficulties and improve the problem-solving abilities of chemistry students. Currently, the instructional strategies being used in chemistry teaching have not realised considerable improvements in the quality of students' achievement in the subject to a considerable extent. As a result, developing better strategies of teaching chemistry has been and is becoming one of the core issues that scholars deal with in chemistry education. The focus on improving learners‟ problem-solving skills using problem-solving instructional strategies to foster a deeper and more meaningful understanding of stoichiometry therefore becomes important for chemistry educators.

OBJECTIVES, RESEARCH QUESTIONS AND HYPOTHESES

The study addressed the following objectives:

i. To determine the effect of the [18] problem-solving model and the [19] problem-solving model on the academic achievement of students in stoichiometry.
ii. To determine if gender has an influence on the achievement of students in stoichiometry when exposed to the [18] as well as [19] problem –solving models.

The following Research Questions guided the study:

1. What is the difference in the mean achievement scores of students taught with [18] and [19] problem-solving models and those taught with the conventional method?
2. To what extent would gender influence the mean achievement scores of students taught with [18] and [19] problem-solving models in stoichiometry and ionic equilibria.

The study tested the following research hypotheses:

HO1: There is no significant difference in the performance of students taught using the two problem-solving instructional strategies and those taught using lecture methods.

HO2: There is no significant difference between the performance of female and male students taught stoichiometry using the two problem-solving instructional strategies and those taught using lecture methods.

RESEARCH METHODOLOGY

The study employed a quasi-experimental research approach with a non-randomized, non-equivalent pre-test and post-test control group. In this study, intact classes were used instead of randomly composed samples since, school classes exist as intact groups and school authorities would not allow the classes to be taken apart and rearranged for research purposes. The use of intact classes made it possible for the researcher, to administer a treatment or intervention to some of the classes while the other classes act as the control [20]. The views of [21] seem to suggest that random selection is not possible in educational research, while [22] observes that researches involving the effectiveness of teaching strategies to improve student achievement random assignment are rare. Since it was not possible for the researcher to conduct a true experiment, non-equivalent control group design was used in the study [23].

The sample comprised of 525 Advanced Level chemistry learners. The participants were drawn from eight high schools in the district. Two hundred and seventy-five (275) of these participant learners (from four schools) formed the control group, while the other 250 learners from four of the remaining schools constituted the experimental group. The learners in the control group (schools) were taught by their teachers using the conventional lecture method. The learners in the experimental group (schools) were also taught by their teachers who served as research assistants after having been trained on the use of problem-solving instructional strategies. These research assistants implemented problem-solving instruction in their classes.

Data for this study were collected using problem-solving achievement tests in stoichiometry. The test comprised of multiple choice and open ended items. The test was validated by experts in chemistry education before its use in the pilot as well as in the actual study. The internal consistency of the test was evaluated using Cronbach alpha coefficient and found to be 0.84, which is an acceptable level of reliability. The analysis of data was carried out using both descriptive statistics (mean, standard deviation) and inferential statistics (analysis of covariance, ANCOVA) using Statistical Package for Social Sciences (SPSS) version 20.0. The post-test score for stoichiometric problem-solving test was subjected to Analysis of Covariance (ANCOVA) using pre-test scores as covariates. The use of ANCOVA analysis was to "statistically control" for influence of confounding variables. A p-value of less than 0.05 was considered to be statistically significant.

FINDINGS

The results of the study are presented based on the research questions and research hypotheses formulated. All hypotheses were tested at 0.05 level of significance.

Research Question one:

What is the difference in the mean achievement scores of students taught with Ashmore, Casey and Frazer (1979) and Selvaratnam and Frazer, (1982) problem-solving models and those taught with the conventional method?

To address this research question, a comparative analysis of the effects of the Selvaratnam-Frazer as well as Ashmore et al. problem solving approaches on Advanced Level students' achievement in Stoichiometry was made. The results of the post-test indicated that the experimental schools had greatly improved when compared to control schools as shown in tables 1 below.

Table 1: Mean scores and standard Deviations (SD) of students in Stoichiometry

Group	Mean	Standard deviation	N
Control	40.6160	1.15667	250
Exp- Ashmore et al	56.7179	1.15852	117
Exp-Selvaratnam-Fraser	56.6949	0.99149	118
Total	48.4124	8.12678	485

From the data presented in table 1, it was observed that the students in the two experimental groups (Selvaratnam-Frazer and Ashmore et al) had mean scores of 56.6949 and 56.7179 and corresponding Standard deviations of 0.99149 and 1.15852 respectively. The mean score for the students in the control group was found to be 40.6160 and the standard deviation being 1.15667. The observation implied that the use of the two models indicated a positive effect on the students' achievement in stoichiometry.

The study went on further to statistically test the main effect of Selvaratnam-Frazer and Ashmore et al problem-solving instruction on participants‟ overall performance in stoichiometry. In this study, the use of ANCOVA enabled the researcher to isolate the effect of Selvaratnam-Frazer and Ashmore et al problem solving instructional strategies after having statistically removed the effect of the covariate (pre-test scores).

The following null hypotheses (Ho) was tested at 0.05 levels of significance.

Null hypothesis: *Ho: There is no significant difference in the mean achievement scores of students' taught using the Selvaratnam-Frazer and Ashmore et al problem-solving models and those taught with the conventional method.*

Alternate hypothesis: *H1: There is a significant difference in the mean achievement scores of students' taught using the Selvaratnam-Frazer and Ashmore et al problem-solving models and those taught with the conventional method.*

The results of the hypothesis test are presented in table 2 below.

Table 2: The test of Between-Subjects Effects; Stoichiometry test

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Pretest	4.312	1	4.312	3.459	.084
Group	31140.261	2	15570131	12491.765	.000

The result in table 2 suggests that the treatment (Selvaratnam-Frazer and Ashmore et al problem-solving models) is a significant factor on students' achievement in stoichiometry. Thus the hypothesis H0 that there is no significant difference is rejected. The implication is that a significant difference exists in the mean scores of subjects exposed to the two problem-solving models and those not exposed.

Research Question 2

To what extent would gender influence the mean achievement scores of students taught with Selvaratnam-Frazer and Ashmore et al problem-solving models in the Stoichiometry Achievement Tests?

Table 3: Mean Achievement scores of male and female students in the Stoichiometry Achievement Test

Group	Gender	Mean	Standard deviation	N
Control	female	40.9912	1.25519	113
	male	40.8613	1.13230	137
Exp Selvaratnum-fraser	female	51.2542	2.16232	59
	male	51.6271	1.63895	59
Exp- Ashmore et al	female	56.0690	3.28667	58
	male	56.5085	1.26454	59

Table 3 shows that the males in the two respective experimental groups had higher mean scores than their female counterparts.

The following hypothesis was tested at the 0.05 levels of significance.

Ho1: *There is no significant difference in the performance of male and female chemistry students exposed to Selvaratnam-Frazer and Ashmore et al problem-solving models*.

H1: *There is a significant difference in the performance of male and female chemistry students taught using Selvaratnam-Frazer and Ashmore et al problem-solving models*.

Table 4. ANCOVA summary Table for post-test Performance Scores based on gender

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	21692.770[a]	6	3615.462	1181.139	.000	.937
Intercept	5643.119	1	5643.119	1843.557	.000	.794
pretest	31.654	1	31.654	10.341	.001	.021
gender	5.743	1	5.743	1.876	.171	.004
group	21335.570	2	10667.785	3485.071	.000	.936
gender *group	7.922	2	3.961	1.294	.275	.005
Error	1463.155	478	3.061			
Total	1103092.000	485				
Corrected Total	23155.926	484				

The data in table 4 indicates that the F-ratio for the gender factor was not significant since 0.05 is less than 0.171 ($P>0.05$). The conclusion is that there was no significant difference between the mean achievement scores of male and female students taught stoichiometry using the models.

Scheffe's post hoc analysis

To determine which of the two methods was most effective in teaching stoichiometry, a post-hoc analysis was conducted using Scheffe's Post Hoc test. The results are summarized in table 5.

Table 5. Scheffe's post hoc analysis for students' performance on the stoichiometry test

group	N	Subset		
		1	2	3
contr	250	40.9200		
exp-Selvaratnam-Fraser	118		51.4407	
exp-Ashmore et al	117			56.2906
Sig.		1.000	1.000	1.000

The results in table 5 show that learners in the two experimental groups are significantly different from those in the control group and that their performance was better than those in the control group. Moreover, the Scheffe's post-hoc test also indicated that there was a significant difference between the two experimental groups (those taught using the Ashmore et al problem solving model did significantly better than those taught using the Selvaratnam-Frazer problem-solving model.

DISCUSSION

Generally, the findings of the study revealed that problem-solving instruction is more effective on improving problem-solving skills of chemistry learners in stoichiometry than the conventional teaching method. The finding of this study is in consonance with the view of [24, 25] who assert that problem-solving instruction enhances achievement in Chemistry more than conventional lecture method of teaching. This result is in agreement with the results of earlier studies carried out by [26] as well as [27] both of which established the relative efficacy of problem-solving instructional strategies in fostering students' achievement in school subjects relative to the expository method. The findings are in accord with [28] who noted that the use of problem-solving instruction significantly increased students' achievement in computer programming.

With reference to the second research question (To what extent would gender influence the mean achievement scores of students taught with problem-solving instructional strategies?), the effect of problem-solving instruction on stoichiometry problem-solving abilities and achievement of female and male students in the treatment group was not found to be statistically significantly different. Literature has reported many findings [29, 30, 31] revealing the exceptional performance of male students than their female counterparts in science. However, in the present study problem-solving instruction reduced the gender gap in stoichiometry problem-solving skills and performance indicating that gender is not a perfect predictor as far as achievement in stoichiometry concerned, whether students are taught using problem- solving approach or the conventional method. This finding was also in consonant with [32] as well as [33] that gender has no effect on students' performance in chemistry and physics respectively, a position also held by [34] who also found out that gender difference had no influence on students' performance in chemistry and science examinations.

The findings of men out performing women may perhaps have been perpetuated by gender stereotyping which is commonly based on cultural beliefs. This finding implies that whether a student is male or female, gender does not make a difference in their academic achievement therefore students' academic achievement is not a function of gender. All students irrespective of their sexes benefited in about the same margin from the use of problem-solving instructional strategies.

CONCLUSIONS

It can therefore be concluded that the application problem-solving strategies is more effective in helping students improve their problem solving performance than conventional lecture method. This clearly supports the implementation of problem-solving instruction in the chemistry classroom. The implication is that students who were taught using problem-solving strategies had well mastered the strategies of solving stoichiometry and ionic equilibrium problems better than those taught using the conventional method.

The gender difference among students exposed to problem-solving instruction was not significant implying that problem-solving instruction is capable of facilitating learning in similar manner among male and female students in stoichiometry and ionic equilibria.

Recommendations

Based on the major findings of this study, the following recommendations are made:

It is evident from the study that, problem-solving instructional teaching methods are effective in improving students' achievement in stoichiometry and ionic equilibria. Therefore, chemistry teachers are strongly recommended to use these teaching methods in their lessons to facilitate students' problem solving performance.

Considering that the goal of chemistry education is to improve problem solving skills of learners, findings from the study suggest need for proper training of pre service teachers in problem solving instruction as well as how to implement effectively problem-solving instruction. Furthermore, in-service training through symposiums and workshops should be organized and made compulsory for practicing chemistry teachers so that they can embrace the skills of the problem-solving strategies for effective implementation of the strategies in teaching chemistry.

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