Gender Related Differences in Acquisition of Formal Reasoning Schemata: Pedagogic Implication of Teaching Chemistry Using Process-Based Approaches

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Abstract

The study was carried out to determine the effects of process based instruction on acquisition of formal reasoning ability in male and female Subjects under study. To determine the gender related differences in acquisition of formal reasoning ability 38 Subjects randomly selected from a Secondary School in Kaduna State, Nigeria were pre-tested using Group Assessment of Logical Thinking Test (GALT), after which they were exposed to process-based instruction for six weeks. The male and female subjects' posttest scores were compared using t-test statistics. The initial gap between the male and female subjects in formal reasoning ability was bridged in all the Schemata (conservation, control of variables, proportional reasoning, probability reasoning, and combinatorial reasoning) except in correlational reasoning. Based on the results, one of the major recommendation made was that process-based instruction should be introduced in the early years in the Secondary Schools as means to reduce if not totally eliminate the gender-related differences in reasoning ability between male and female students in secondary schools.

1. Introduction

Many science educators have expressed concern over narrow participation in science technology courses as well as the low number of women who hold a professional career in science or technology Samba, [12]. This has stimulated many researches to identify reasons and possible ways of making science more attractive to girls. A number of reasons have been advanced for gender difference in science achievement. Studies by Becker [4] attributed the sex difference in achievement to teachers who according to them spoke more frequently to boys, asked the boys higher order questions and praise them for quality work and girls for neatness. Sadket and Sadker [11] noted that male students received more praises and criticisms from the teachers than the female students. Boys domination of practical activities that are known to enhance acquisition of science and reasoning skills in the class is considered as one of the major reasons for the difference in reasoning ability between boys and girlBullock[6]. Boys are known to have higher self-efficacy for leaning science than girls and this tend to give them more confidence and greater influence over girls in designing and conduct of laboratories activitie. Thus, the prevalent circumstances in the classrooms predispose boys to take charge or dominate science activities whenever they are paired to work with girls. Another reason advanced for the sex differences in science reasoning was advanced by Shernesh [13] who attributed gender related differences to reasoning skill. Many studies, Graybill, [6]; Howe & Shayer, [7] and Mari, [10] demonstrated that boys are superior to girls in their level of performing Piagetian like formal reasoning tasks. Individuals who perform Piagetian tasks are said to have acquire formal reasoning which is defined as the ability to construct concepts by engaging abstract or hypothetico-deductive reasoning skills like proportional reasoning, controlling variables, probability reasoning, correlational reasoning and combinational reasoning. Piaget observed that at formal operational stage we have acquired abstract, logico-mathematical reasoning capacities that allow us detach ourselves from the object world so that we can reason about it in strictly logical terms.

Students who have acquired formal reasoning ability have deep working memory that enable them solve abstract problems in logical fashion. They are also able to apply scientific thinking in solving problems such as stating and testing hypotheses, isolation-of-variables, analyzing data, and ability to keep concepts and their interrelationships in the mind while considering answers. According to developmental theory, descriptive and theoretical concepts constructions are linked to intellectual development because the process depends on reasoning patterns and also reasoning ability relies on not only maturation but also individual self-regulatory mechanisms that are known to enhance purposive and meaningful learning. This tend to suggest that concept acquisition is dependent on students' reasoning ability. Empirical study in support of this was provided by Lawson[11] who reported that reasoning ability highly correlated with performance on concepts acquisition tasks for school Biology and chemistry students. Bitner[5] also showed that reasoning ability explained 62% of the variance in high school science grades. Herron [9] provides the following generalizations that link misconceptions with reasoning ability:

1. Many misconceptions are related to concepts that involve proportional relationships: density, equilibrium, mole, acceleration, and rates of various kinds.
2. Many misconceptions are related to theoretical models that require the student to interpret observations in terms of something that cannot be experienced directly: explanations in terms of genetics and evolution, explanations in terms of an atomic model, and explanations in terms of probabilistic models.
3. Many misconceptions are related to difficulty in following chains of logical inference

All these arguments point to the significance of reasoning ability to concepts acquisition in science and could also be indication why girls who happen to lag behind boys in reasoning ability perform lower and show less preference for science compared to boy.

Shemesh [13], in a survey of students cognitive development in Israel revealed that gender related differences in performance of Piagetian-like tasks were not observed before the ninth grade (14 - 15 years). According to him some researchers have identified teaching strategies as a cause of sex-related differences in science performance. For example Ajewole [2] studied the effects of the guided discovery and expository instructional methods on students transfer of learning. Analysis of the result revealed no significant difference in the transfer of learning between male and female students exposed to guided discovery and expository methods. Mari [8] and Ajagun [1] in independent studies however demonstrated the superiority of girls over boys in use of science process skills. In the studies, girls were found to be superior in the use of skill of observing, inferring, predicting, hypothesizing, making operational definition and interpretation of data. The boys on the other hand, were better than girls in experimenting and measuring. This suggests that process-based instruction could enhance female students' achievement in science better than their male counter-part, as female subjects in the studies were found to perform better than male subjects in science process skills. Of greater interest, is the link that has been established between the acquisition of science process skills and formal reasoning ability. Baid and Borich [3] investigated the correlation between science process skills and formal reasoning and reported that the two variables though different are significantly correlated. Good [5] pointed out that exposure to systematic science programme, which emphasizes integrated science processes may promote cognitive development. Since girls are superior to boys in use of science process skills may suggest that the use of science process skills instruction may promote cognitive growth in girls than boys. This study is aimed at establishing the gender-related differences in acquisition of formal reasoning ability as a result of exposure to process-based -instruction.

2. Research rationale

The literature suggests that formal reasoning ability can only be acquired if the right instructional medium is provided. The suitability of instructional method is determined by its viability in promoting the acquisition of formal reasoning and problem solving ability in learners. This study therefore, was to establish, if exposure of Secondary School Students to process-based instruction would significantly improve their reasoning ability.

Studies have revealed that boys are superior to girls in reasoning ability Howe and Shayer, [7]. They recommended, based on their findings, the need to adopt teaching strategies that will enhance acquisition of reasoning ability in girls. Mari [9] has established that process-based instruction enhances acquisition of reasoning ability in students. The fact that girls are superior to boys in use of science process skills, may be an indication that science process-based instruction would promote cognitive gains in girls more than boys. The purpose of this study, is thus to establish if:

(i) Boys and girls differ significantly in their reasoning ability.

(ii) Exposure to science process-based instruction will bridge the gap in reasoning ability between male and female subjects.

The following research questions were stated:

(i) Do boys and girls differ significantly in acquisition of formal reasoning ability?

(ii) Do boys and girls differ significantly in ability to use conservation reasoning, proportional reasoning, control of variables correlational reasoning, combinatorial reasoning and probability reasoning?

To answer the questions, the following null hypotheses were stated:

(i) Boys and girls do not differ significantly in acquisition of formal reasoning ability.

(ii) Boys and girls do not differ significantly in ability to use conservation, proportional - reasoning, control of variables, correlational reasoning, combinational reasoning and probability reasoning.

3. Methodology

A total of thirty-eight Senior Secondary II students obtained from one school through a process of randomization were used as the sample. Their average chronological age was sixteen years. After the subjects were pretested using GALT, they were exposed to process-based instruction for three hours a week for six weeks. The subjects were exposed to two lessons of one hour thirty minutes each week. The goal of the instruction was to facilitate the acquisition of scientific skills in students to enable them function as scientists. The subjects were exposed to activities designed to allow them work independently, follow series of instructions as guidelines to assist them to successfully formulate hypotheses, design experiments, interpret data and proffer conclusions and generalizations that are of scientific interest. The activities were infused into topics like neutralization reaction, determination of purity of liquids through boiling point, qualitative analysis and rates of reaction. However, the goal was not to teach the chemistry concepts but to assist the subjects acquire scientific skills. All the activities were meant to provide the learners the opportunity to learn how to formulate hypotheses, design experiments and interpret data. In every process-based activity given, subjects were provided with reagents, allowed to state a hypothesis and design experiment to test this hypothesis. They were required to give a detailed procedure of the experimental design and reasons they arrived at the procedure. Subjects' note books were then marked and their procedures were discussed and appraised in the class. The various ways of improving upon the designs were provided. Interaction among the subjects in the experimental group was not allowed during the activity to provide every subject ample opportunity to individually reason out their solutions to problems posed.

The posttest scores of the male and female subjects on GALT were tested using t-statistics, for any significant difference in the mean scores.

4. Results

Group Assessment of Logical Thinking Test (GALT) which measures six formal reasoning schemata, was used to measure the level of the cognitive development of the subjects. The results are presented in tables 1 -7.

Table 1. Comparison of the pretest mean scores of the male and female subjects in conservation, proportional reasoning, combinatorial reasoning, correlational reasoning and probability reasoning before treatment (N=38)

Schemata	d f	t-value	P
Conversation	36	1.87	0.060
Proportional reasoning	36	2.85*	0.004
Control of variables	36	1.50	0.90
Correlation reasoning	36	3.06*	0.001
Combinatorial reasoning	36	1.58	0.82
Probability reasoning	36	2.53*	0.02

*NS = Significant at $P<0.05$ level

The results in table 1 show that there is significant difference in performance between the male and female subjects in proportional reasoning, correlational reasoning, and probability reasoning. Though, the male subjects performed better than their female counterpart, in conversation, combinatorial reasoning and control of variables, however the difference in the mean score was not significant at P# 0.05 level.

Table 2. Comparison of the mean score of the male and female students in the conservation after treatment

Group	N	X	SD	Df	t-Value	P
Male	22	0.82	0.80			
Female	16	0.50	0.730	36	1.26*	0.22

*NS = Not significant at $P<0.05$ level

Table 3. Comparison of the Pottest Mean Score of the Male and Female Subjects in the Experimental Group in Proportional Reasoning

Group	N	X	SD	Df	t-Value	P
Male	22	1.00	1.02			
Female	16	1.00	0.82	36	0.00*	1.00

*NS = Not significant at $P<0.05$ level

The result in Tables l and 2 indicate that male and female subject do not differ significantly in performance after instruction. This shows that the female subjects have been able to match the performance of their male counterpart in proportional reasoning by the end of the treatment.

Table 4 . Comparison of Male and Female Students' Posttest Mean Score in the Control of Variables After Treatment

Group	N	0	SD	Df	t-Value	P
Male Female	22 16	0.32 0.63	0.73 0.72	36	1.0^{NS}	0.28

NS = Not significant at P<0.05 level

The result of the t-test analysis in Table 3 revealed no significant difference in the subjects' ability to control variables after exposure to treatment. Though, there is no significant difference in performance, however, the mean score of the female subjects is higher than that of the males. This is an indication that the female subjects tended to have benefitted more from the treatment than their male counterpart.

Table 5. Comparison of the Posttest Mean Scores of the Male and Female Subjects in Correlational Reasoning after Treatment

Group	N	x	SD	Df	t-Value	P
Male Female	22 16	1.18 0.5	0.85 0.63	36	2.70*	0.011

* = Significant at P< 0.05 level

Results in Table 4 show that the male subjects performed significantly better than the female subjects. This observation is empirical evidence that correlational reasoning is a very complex skill that can only be acquired when the prerequisite skills required for its development have been formed. The female subjects performed significantly lower than the male subjects at the beginning of instruction, thus, the treatment period might have been too short for the prerequisite s to develop and equilibration to take place for the correlation skill to be established.

Table 6. Comparism of the Mean Scores of the Male and Female Subjects in Combinatorial Reasoning After Treatment

Group	N	0	SD	Df	t-Value	P
Male Female	22 16	1.00 1.00	0.82 0.82	36	0.00*	1.00

*NS = Not significant at P< 0.05 level

From the results in Table 5, it can be seen that there is no significant difference in the comparison of the mean scores of the male and female subjects in combinatorial reasoning.

Table 7. Comparison of the Mean Scores of the Male and Female Subjects In probability Reasoning After Treatment

Group	N	0	SD	Df	t-Value	P
Male Female	22 16	0.55 0.63	0.08 0.81	36	0.30^{NS}	0.76

NS = Not significant at P< 0.05 level t B critical 1.68

The results in Table 6 show that there is no significant difference in the performance of the male and female subjects in probabilistic reasoning.

5. Discussion

The results in tables 2 - 6 show that there was no significant difference in the performance of the male and female students in all the Schemata, except the Schema of correlational reasoning in which the male Subjects performed significantly better than the females. The treatment administered seems to have helped in bridging the gap in reasoning ability between male and female subjects in all the Schemata except correlational reasoning in which the male Subjects' superiority over the females persisted even after treatment. This may suggest that the correlational reasoning is a complex schema, which can only be attained when the pre-requisites schemata are acquired. The gap in mean scores in correlational schema between male and female group was however narrowed, which is an indication that if the treatment period was extended the gap would have been bridged.

The initial gap between the male and female Subjects in formal reasoning ability was bridged in all the schemas (conservation, control of variables, proportional reasoning, probabilities reasoning, combinational reasoning) except in correlational reasoning. This shows that the process-based instruction tends to have stimulated higher reasoning gains in the female Subjects than the male subjects. This supports observations by Mari [8] and Ajagun [1] that process-based learning tend to benefit female students more than males.

6. Recommendation

The science process-based instruction tends to have stimulated higher-reasoning gain in female subjects than the males. There is, therefore, the need to use science process-based instruction in the early years in Secondary School as a means to reduce, if not totally eliminate, the male/female difference in reasoning ability.

7. Conclusion

The present study indicates that process-based instruction aid in bridging the gap in ability to use all schemata except correlational reasoning. It seems feasible that if the period of research was extended the gender related difference might have been bridged in all the schemata as the difference in mean score of the males and females in correlational schema was narrowed, though it was significant. It also established that though process based instructions promotes cognitive gains in both males and females, females exposed to process based instruction tend to show more appreciable increase in reasoning ability. Thus, process based instruction can be effectively used to create a balance in reasoning ability between males and females students. As the major reason for low women enrolment in science has been attributed to its abstract nature of concepts which requires high level of formal reasoning ability to comprehend or abstract, the use of process-based instruction could inspire more female to enroll in science or science related careers. This is because its use will raise their reasoning ability to the level required for meaningful engagement in learning of formal or abstract concepts. The fact that all subjects witnessed appreciable increase in reasoning ability is an indication that teachers can influence learners reasoning ability by adopting right instructional strategies. It also an indication that reasoning ability is environment-dependent and could be influenced wherever the right environment is provided for learning.

8. References

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