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The Effect of Homogenous and Heterogeneous Gender Pair Cooperative Learning Strategies on Students' Achievement in Chemistry

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Authors' contributions

This work was carried out in collaboration between all authors. Author FAA designed the study, wrote the protocol and supervised the work. Authors OMN and NAO carried out all field work and author NAO performed the statistical analysis. Author NAO managed the analyses of the study. Authors OMN and NAO wrote the first draft of the manuscript. Authors OMN and NAO managed the literature searches and author NAO edited the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

This study determined the effect of homogenous and heterogeneous gender pairing cooperative learning strategies on students' achievement in Chemistry at the secondary school level. Mental ability was the moderating variable and three hypotheses were tested at 0.05 level of significance. The study adopted a pretest-posttest, control group, quasi-experimental research design. A total of 300 students were randomly selected from 6 schools (2 mixed schools, 2 boys' only schools, and 2 girls' only school). The instruments used in the study were: Students' Chemistry Achievement Test (SCAT), Students' Mental Ability Test (SMAT), lesson notes on the periodic table and teachers'

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instructional guides for the three treatment and control groups. The results revealed significant main effect of treatment on students' achievement in Chemistry. The two-way interaction effect of treatment and mental ability on students' achievement was also significant. It is concluded that when students learn Chemistry concepts like periodicity and the rate of chemical reactions through gender pairing teaching strategy, their mental abilities determine the effect of the teaching strategy on their performance.

Keywords: Secondary school students; cooperative learning; gender.

1. INTRODUCTION

The teaching and learning of Chemistry as a school subject at the secondary school level is central to science education. However, [1] observed that many factors such as the mathematical nature of Chemistry, the abstract nature of Chemistry concepts and laws, and poor teaching methods, account for students' poor performance in the subject. Among the notable factors affecting students' achievement in Chemistry, the instructional strategies employed by teachers appear to be of notable prominence [2-4]. [5] defined teaching method as the vehicle through which a message is delivered and further asserted that the wrong perception of Chemistry by students may imply that Chemistry is being taught through the wrong method or approach. Effective teaching is fundamental to learning and the products of teaching which include knowledge, attitude and aptitude, are dependent on effective teaching.

Several strategies of teaching have been designed to teach Chemistry and the effects of these strategies have been significant. These strategies include concept mapping instructional strategy [4]; laboratory instructional strategy [6]; role instructional model [7] and others. The effectiveness of the teaching and learning process can be facilitated through the appropriate strategy adopted in a learning situation. Chemistry is a subject with many concepts, some of which are abstract in nature, and secondary school students often find the abstract concepts difficult to understand [8-10]. [11] asserted that the cognitive demands of the course content, the mathematical base and the language of Chemistry are what make students perceive the subject as challenging.

In order to reduce the challenges students face when learning Chemistry, Student-centered cooperative learning strategies have been recommended as a superior alternative to the teacher dominated "sage on the stage" nature of the conventional lecture method. Cooperative learning strategies have many positive effects on students' performance [12-19]. [20] defined cooperative learning as the instructional use of small groups such that students work together to maximise their own and each other's learning. Cooperative learning strategies have been observed to enable students to control their learning processes actively. This enhances motivation and academic achievement; and it also improves social relations relative to traditional whole class methods of teaching [21,22].

Similarly, [23] noted that cooperatively taught students tend to exhibit higher academic achievement, greater persistence through graduation, and better higher-level reasoning and critical thinking skills. In addition, students tend to achieve a deeper understanding of learned material, greater time-on-task, and lower levels of anxiety and stress. Cooperative learning also leads to greater intrinsic motivation to learn and greater ability to view situations from others' perspectives in a more positive and supportive relationship with peers and students develop higher self-esteem.

During the last two decades, a lot of research studies done on cooperative learning in Science and Mathematics point out the advantages of cooperative learning strategies. Research shows that most students learn best from working with other students [24]. This stems from the cognitive advantage of being able to share ideas and vocalize thoughts as the students interact with friends and fellow classmates [16]. Research has also shown a positive effect of cooperative learning strategies on students' Chemistry achievement [25,26]. [27] found in their research that the teaching of Chemistry concepts through cooperative learning methods was more effective in increasing academic achievement compared to the traditional teaching methods.

Pairing in cooperative learning has been regarded as simple and efficient because cooperative reward structures raise the value students place on academic learning and

changes norms of academic achievement [28]. Paired students are said to have the advantage of drilling and practising with one another. Most pairing techniques are based on ability levels, compatibility, assertiveness, speed and gender [29,30].

Researches on various categories of grouping/pairing in cooperative learning have been carried out. For example, students have been grouped according to their achievement levels – high medium and low level achievers [31,32]. Students have also been grouped according to gender [33-38]. Some researchers suggest that the composition (homogeneity and heterogeneity) of cooperative group membership may have a role in achievement and attitude [39]. [40] found that homogenous cooperative groups performed significantly better than heterogeneous groups.

Moreover, gender differences in the effectiveness of cooperative learning strategies have also been researched by various scholars [33-38]. [41] investigated gender differences in cooperative problem solving in gifted students. She found no statistically significant difference in students' achievement or self-efficacy in single or mixed gender groups. [42] found no significant gender related differences, but females achieved slightly higher grades than males. However, other researchers believe that males thrive better in a competitive environment while females excel in a cooperative classroom setting [43,44]. [45] found that boys performed better than girls in both cooperative and competitive learning strategies when he investigated the effect of cooperative and competitive learning strategies on Nigerian students' academic performance in Mathematics.

Apart from general gender differences, researchers also disagree as to which type of gender pairs work most productively. One study claims homogeneous pairs consisting of either males or females work best [46]. Another study claims that heterogeneous pairs (males and females) work most effectively [47]. Some found male pairs to be more effective than female pairs [48]. Others found female pairs to be more effective [49,50]. [46] found no difference in performance between males and females pairs. Furthermore, previous investigations on the effect of gender on students' achievement in Chemistry showed that males often outperform their female counterparts [51,52]. Very few research studies showed that female students are superior or comparable to males [53]. Identifying the type of gender pair cooperative learning strategy which has the potential to adequately improve the achievement of either gender will be a great asset to instructional delivery in Chemistry at the senior secondary school level as well as help to bridge the achievement gaps attributed to gender.

Furthermore, the effectiveness of cooperative learning depends on the social competence of the paired students. Social competence encompasses a variety of social behaviors and capacities that enable individuals to interact more effectively with others [54]. [55] conceptualised social competence as peer status. The effectiveness of interaction with others can only be determined by an individual's ability to cooperate or compete. As a result of this, the ability to initiate and maintain friendship with pairs is critical in the effectiveness of a team. The type of cooperation this study aims at among pairs is hinged on reciprocal altruism [56] such that all members of the group are rewarded after the task is completed successfully. According to [54] there is evidence that girls are less likely than boys to have equal access to activities and materials in educational settings, most especially in mixed sex contexts. [57] concluded that boys tend to dominate learning resources in mixed sex group. The dominance of boys has been largely attributed to their ability to compete more than the girls [58]. Girls have been observed to play in smaller groups and to engage in more intimate social interactions, turn taking, and cooperative endeavours [54]. Competitive interaction among boys unlike the communal or cooperative interaction among girls usually inhibits learning when paired homogeneously. However, the communal interaction of girls facilitates learning when they are paired homogenously. The heterogeneous gender pair is a blend of competition and cooperation. Therefore, the pendulum of effectiveness of learning in such pairings may be beneficial to or detrimental to either males or females.

In addition to teaching strategies, during the past decade, researchers in Science Education have brought to light the importance of cognitive factors influencing achievement in Science courses [58]. Mental ability is one of the cognitive factors that influence learning. [59] identified the following aspects of mental abilities: verbal comprehension, spatial orientation, number facility, word fluency, associative memory and perceptual speed. Mental ability tests have been

used extensively in schools as a basis for classifying pupils and as aids to supervisors and administrators in diagnosing the difficulties which pupil have with their work [61]. Mental ability is the capacity to perform high mental reasoning, remembering, understanding and problem solving [62]. Investigating the relationship between mental ability levels and students' learning outcomes cannot be relegated to the background of any scholarly work in the field of education.

Several research studies have been carried out to investigate the effect of mental ability on students' academic performance [63-66]. [63] found no significant difference in the performance of students in Chemistry based on their mental ability levels (high, average and low) in Chemistry. However, [66] found discrepancies in the performance of Chemistry students of different mental ability levels. Several researchers have also investigated how mental ability affects the outcome of a cooperative enterprise [65,67,68]. Similarly, most of the aforementioned studies measured the numerical aspect of students' mental ability as it influences students' achievement in Chemistry.

However, it has been argued that general mental ability is more important than other specific mental abilities identified by [60] because general mental ability explains variations in individual performance [62] General mental ability also measures a variety of specific constructs such as numerical ability, spatial ability and verbal concepts among others. Also, the nature of the problems in periodicity and the rate of chemical reactions do not restrict students to engage in only one aspect of intelligence or mental ability. Rather, it requires a combination of all the types of mental abilities. Against this background, this study determined the effect of homogenous and heterogeneous gender pairs on secondary school students' achievement in the aspects of the periodic table and the rate of chemical reactions using students' general mental ability as the moderating variable.

1.1 Null Hypotheses

(Ho_1) There is no significant main effect of treatment on students' academic achievement in Chemistry.

(Ho_2) There is no significant main effect of mental ability on students' academic achievement in Chemistry.

(Ho_3) There is no significant interaction effect of treatment and mental ability on students' academic achievement in Chemistry

2. METHODOLOGY

A pretest/posttest, control group, quasi-experimental design was adopted for this study. The treatment was varied at four levels as follows: Girl/Girl homogeneous gender pair cooperative learning strategy, Boy/Boy homogeneous gender pair cooperative learning strategy, Boy/Girl heterogeneous gender pair cooperative learning strategy and the conventional teaching method (control group). Students' mental ability which is the moderating variable was classified into three levels of high, moderate and low. The researchers applied for and obtained permission to conduct this research from the Benue State Ministry of Education, Nigeria, after presenting a letter of introduction from the University of Ibadan. The principals of the schools were later presented with the same letter after the ministry's approval was acquired. The participants were chosen from six (6) randomly selected groups (2 all-males, 2 all-females, and 2 co-educational) secondary schools in Makurdi Local Government Area, the capital of Benue State. Intact senior secondary school two (SSS2) Science classes were used in the study. Teachers of the selected classes were used as research assistants after they were trained. In the mixed schools, students were assigned to the three experimental groups and the control group. In the first mixed school, the boys were separated from girls in the class. Hence, the boy/boy and girl/girl groups formed in the first mixed school were exposed to treatment of boy/boy and girl/girl homogenous gender pair respectively. In the second mixed school, the students were also divided into two randomly without gender bias. A half of the class formed boy/girl treatment group while the second half formed the control. In each of the single sex schools, students were assigned to the treatment that matched the gender category of their school and the second school was used as the control. The Table 1 shows how the students were assigned to groups. All the groups were all assigned randomly.

3. INSTRUMENTS

The following instruments were used in the study: Students' Chemistry Achievement Test (SCAT), Students' Mental Ability Test (SMAT), Teachers' Instructional Guide on Cooperative

Table 1. Assigning of students to treatment

	Mixed gender schools	Boys only schools	Girls only schools
G/B treatment	Present	Absent	Absent
B/B treatment	Present	Present (One of the boys schools)	Absent
G/G treatment	Present	Absent	Present (One of the girls schools)
Control	Present (No gender pairing)	Present (No pairing of boys) The second boys school	Present (No Pairing of Girls) The second girls school

Learning Strategy (TIGCLS) and Lesson notes on the periodic table and the rate of reaction.

The SCAT consists of 40 multiple-choice objective items with four (4) options drawn to test students' knowledge of the periodic table and the rates of chemical reactions which formed the basis for the treatment. The test content covered the periodic table and the rates of chemical reactions as found in the SS2 Chemistry syllabus for first term. The SCAT was administered to a sample of 30 senior secondary school students who were not part of the study, but who were similar in age and class to the students involved in the study. The average difficulty and discriminating indices were determined after the instrument was trial tested. The difficulty range was from 0.4-0.6, while the reliability coefficient of 0.76 was obtained using Kuder -Richardson (20.Kr) because the items do not have the same difficulty index.

The Students' Mental Ability Test (SMAT) is a standardized test adapted from the Australian Council for Educational Research (ACER) for general mental ability testing. It was used to determine the general mental ability of the respondents in this study. It contained multiple-choice objective questions. The test items were administered to thirty students who were not part of the original study. The reliability was determined using Kuder Richardson (20.Kr) and a reliability index of 0.86 was obtained. Respondents who scored 75% and above in the SMAT test were assigned to the high mental ability group. Those who scored within the range of 74% to 37.5% were assigned to the moderate mental ability group, while those who scored less than 37.5% were placed in the low mental ability group.

The Teachers' Instructional Guide on Cooperative Learning Strategy (TIGCLS) contains the roles of the teachers and the students in the cooperative learning situation. Experts in the field of Teacher Education were consulted for face and content validity. Six lesson notes were prepared for the periodic table and the rate of chemical reactions since the treatment lasted for a period of six weeks. The duration for each lesson was eighty minutes (double periods). The pretest lasted for a week. The treatment procedure had the following five major steps: (1) four or five students were assigned to a group based on the homogeneous and heterogeneous gender pairs; (2) members of the same group sat together as the teacher introduced the topic; (3) during instruction, the teacher directed recapitulatory evaluation to the group not to an individual; (4) after the instruction, students were given a task related to the content learned and each member of the team did his or her own part but the group submitted a report of what they had done and any successful group was rewarded. The teacher offered assistance to any group which required guidance in solving the task; and (5) learning was individualised. The teacher directed questions to individuals and the tasks were solved individually. On the other hand students in the control group were not paired. The posttest was administered on the eighth week in both the control and the experimental groups. In addition, prior to the commencement of treatment, the participating teachers (research assistants) were trained on the use of cooperative learning strategies.

4. RESULTS

Hypothesis 1: There is no significant main effect of treatment on students' academic achievement in Chemistry.

Table 2 reveals that treatment has a significant main effect on students' posttest achievement in Chemistry ($F_{(3,287)}$= 87.183 ; $p<0.05$). Therefore, Hypotheses Ho_1 is rejected. This implies that the treatment group combined performed better than the control group.

Hypothesis 2: There is no significant main effect of mental ability on students' academic achievement in Chemistry.

Table 2 also reveals that mental ability has a significant main effect on students' achievement ($F_{(2,287)}$= 25.116; p<.05). Therefore hypothesis Ho_2 is rejected. Students with high mental ability had a mean Score of 17.81, followed by moderate mental ability (14.10) and students with low mental ability (13.08). This implies that students with high mental ability performed better than the students with moderate and low mental abilities.

Hypothesis 3: There is no significant interaction effect of treatment and mental ability on students' academic achievement in Chemistry.

Table 2 shows that the interaction effect of treatment and gender on students' achievement scores is significant ($F_{(6,287)}$=26.378; p<.05; partial eta squared = 0.53). Therefore, Hypotheses Ho_3 is rejected. Estimated marginal means were computed in order to understand the interaction effect.

Table 3 shows that the matrices of the two-way interaction of treatment and mental ability on the posttest achievement score is in the following order: Girl-girl high mental ability (mean=23.5), boy-boy high mental ability (mean=20.9), boy-girl high mental ability (19.89), girl-girl moderate mental ability (17.38), boy-girl moderate mental ability (17.12), boy-girl low mental ability (16.3), boy-boy moderate mental ability (14.52), girl-girl low mental ability (14.50), boy-boy low mental ability (13.93), control group with high mental ability (7.65), control group with low mental ability (7.55) and control group with moderate mental ability (7.36) was the lowest. Since the SCAT has 40 items with one mark allotted to each correct response, only the girl-girl high mental ability students and boy-boy high mental ability were above the average of 20. Fig. 1 show the two way interaction effect plot of treatment and mental ability on students' posttest achievement scores.

Table 2. Summary of ANCOVA of posttest achievement scores of students by treatment and mental ability

Source	Df	F	Sig.	Partial Eta Squared
Corrected model	12	40.525	.000	.629
Intercept	1	328.887	.000	.534
Pretest	1	16.948	.000	.056
Treatment	3	87.183	.000*	.477
Mental ability	2	25.116	.000*	.149
Treatment * Mental ability	6	4.351	.000*	.083
Error	287			
Total	300			
Corrected total	299			

**=Significant at p<.05, a. R Squared = .629 (Adjusted R Squared = .613)*

Table 3. Estimated marginal means of two-way interaction effects of treatment and mental ability

Treatment	Mental ability	Mean	Std. error	95% confidence interval for mean	
				Lower bound	Upper bound
B/B Homogenous gender pair	Low	13.932(a)	.634	12.685	15.179
	Moderate	14.522(a)	.652	13.238	15.806
	High	20.196(a)	1.194	17.847	22.545
G/G Homogenous gender pair	Low	14.509(a)	.772	12.989	16.029
	Moderate	17.380(a)	.796	15.812	18.947
	High	23.497(a)	1.400	20.742	26.252
B/G Heterogenous gender pair	Low	16.305(a)	.733	14.862	17.749
	Moderate	17.124(a)	.715	15.716	18.533
	High	19.892(a)	.991	17.942	21.842
Conventional teaching strategies (control)	Low	7.553(a)	.839	5.901	9.205
	Moderate	7.367(a)	.749	5.891	8.842
	High	7.654(a)	.845	5.991	9.317

a Covariates appearing in the model are evaluated at the following values: pretest = 9.9433

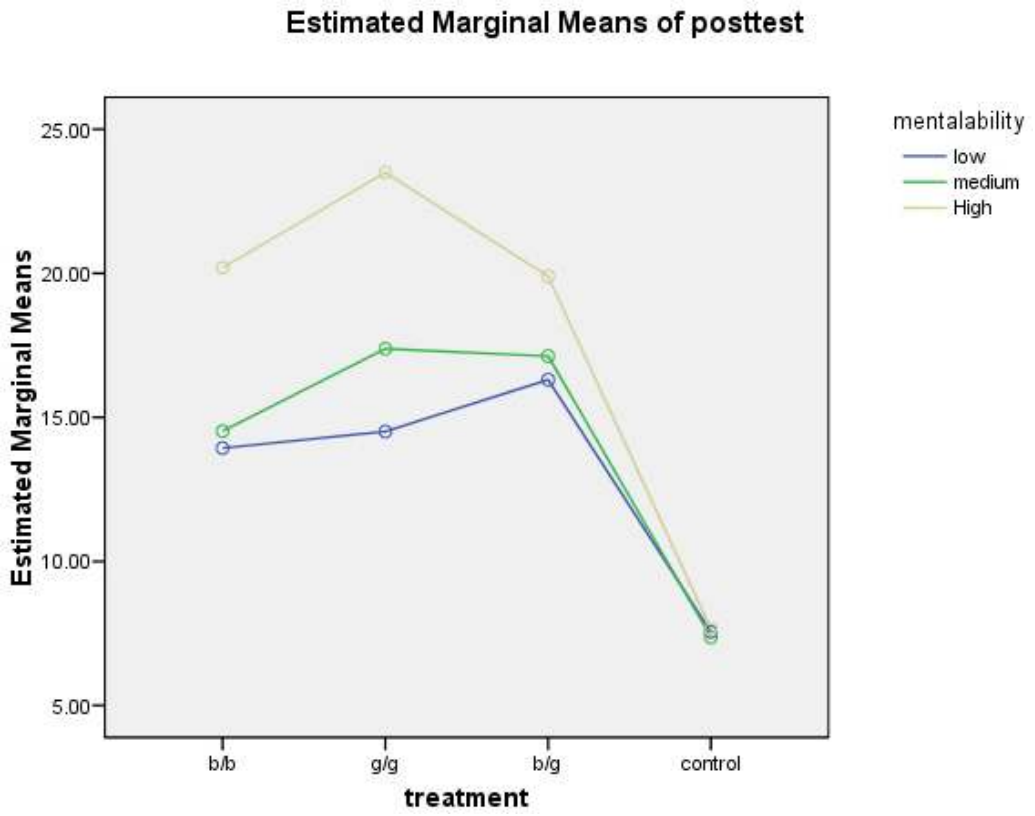

Fig. 1. Graph of interaction effect of treatment and mental ability on students posttest scores

The graph above shows that the interaction effect is dis-ordinal. This implies that no interaction group is always greater than another group. For example treatment/high mental ability groups in this study are always greater than treatment/moderate mental ability groups and treatment/moderate mental ability groups are always greater than all the treatment/low mental ability groups. However this does not apply for the control group/mental ability interaction because the control/high group is greater than control/moderate group but the control/ moderate group is not greater than control/low mental ability group.

5. DISCUSSION

The results obtained revealed that treatment had a significant effect on students' achievement in Chemistry. The achievement mean scores of students exposed to Boy/Boy homogeneous gender pairs, Girl/Girl homogeneous gender pairs, Boy/Girl heterogeneous cooperative learning strategy was better than the conventional teaching strategies.

The two-way interaction effect of treatment and mental ability subsumes the separate significant effect of treatment and that of mental ability. This is an indication that irrespective of the gender pair, mental ability interacts with the treatment before it is effective. Based on the interaction effects, high mental ability students exposed to Girl/Girl homogeneous cooperative learning strategy had the highest posttest achievement mean scores, followed by the high mental ability Boy/Boy homogeneous cooperative learning group, and the high mental ability boy/girls heterogeneous group. Students in the control group had the least mean achievement posttest scores. The success of the treatment may be attributed to the fact that cooperative learning was able to engage the students in the Chemistry class and transform them from passive to active learners. In addition, it kept them engrossed in learning after class as pairs sought out answers to questions contained in structured assignments. This is in line with the findings of [39] that homogenous or heterogeneous gender pairs improve students' achievement and attitude to science subjects. The results may also be attributed to the fact that

paired learning developed in learners critical thinking, reasoning and problem solving skills as they interrogated issues, shared ideas, and classified differences and in the end, constructed new understandings. Furthermore, the high ability girl/girl homogenous gender pair had the highest posttest achievement score. This may be attributed to the fact that in the Nigerian culture, women try to beat men in any competitive task. This is consistent with the views of [69,70] and [71] who believed that single sex groups allow females to be more fully involved in the tasks of the groups, although their findings were not attributed to the high mental ability of the females as it is in this particular case. The results also affirm the findings of [43,72] and [43] that females thrive better in a cooperative environment than males. The high mental ability boy/boy gender pair had the second highest posttest achievement mean scores. Similarly, the third group whose score is close to the average is the high mental ability boy/girl group. It could be inferred from these results that students with high general mental ability benefited more irrespective of their gender pair.

The result (boy/girl gender pair) is inconsistent with studies that found an increase in students' achievement when the number of males and females are balanced in a cooperative learning group [73]. The result of the interaction effect of treatment and mental ability is not in line with the findings of [74] which showed no significant difference in the mixed gender pair and same gender pair in a paper presentation task. The finding on the interaction effect from this research is consistent with the findings of [66]. They found that peer assisted cooperative instructional strategies had an effect on students' performance in Chemistry, although [66] did not moderate treatment with mental ability. The result is also in conformity with the findings of [75] study where it was found that cooperative methods of teaching Chemistry improved students' achievement in Chemistry.

Moreover, it was found that mental ability significantly interacted with treatment to improve students' posttest achievement mean scores in all the treatment groups. This implies that students' mental ability determined how well they perform in the treatment groups. Students with high mental ability benefited more from the treatment group than those with moderate and low mental abilities. This finding agrees with [64] who asserted that students require high mental ability to cope with learning of the subject. They believed that mental ability was a determinant of students' performance and would make a significant contribution to students' achievement in Chemistry. This result also agrees with [76] whose study revealed a significant interaction between students' ability and academic achievement. He reported that more improvement in academic achievement was recorded with high ability students than low ability students regardless of the learning strategy employed.

6. CONCLUSION

Based on the findings of this study, it can be inferred that cooperative learning strategy is effective in improving students' achievement in Chemistry. However, students with high mental abilities benefit most from cooperative learning strategy especially when they are of the same gender pair as noticed for the high mental ability girl/girl and the high mental ability boy/boy groups in this study. Therefore, gender pairing cooperative learning strategy will lead to better performance of students in Chemistry, especially students with high mental abilities.

7. RECOMMENDATION

The study revealed that teaching Chemistry using heterogeneous and homogeneous gender pair cooperative learning strategies has a positive effect on students' achievement. It seems reasonable for Chemistry teachers to consider using these strategies in today's classrooms. This is because these strategies can go a long way in helping them teach difficult and broad topics. These strategies may also improve students' achievement in such topics and learning in general. Chemistry educators in colleges of education and universities should incorporate homogeneous and heterogeneous gender pair cooperative learning strategies in their teacher education programs and in-service courses to upgrade teachers' professional competencies and motivate them to adopt and use these strategies.

It is also essential to carry out further research on how students with moderate and low mental abilities could benefit better from gender pairing teaching strategies to the degree achieved by the high mental ability students. Perhaps, there is also a need to consider students' mental abilities when pairing students by gender. Adequate provisions should also be made for students with low and moderate mental abilities.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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