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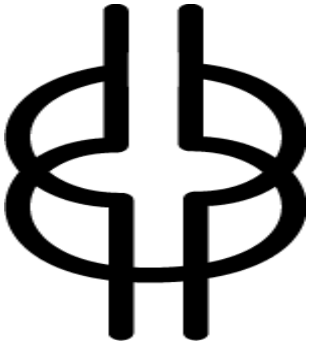

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Comparative Effects of Critical Thinking and Peer-Assessment Skills Training on Ghanaian Senior High School Students' Achievement in Mathematics

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Abstract

The study determined the comparative effects of critical thinking and peer-assessment skills training on Ghanaian senior high school students' achievement in mathematics. The non-equivalent pre-test and post-test control group 3x2x2 factorial quasi-experimental design was adopted for the study. Three public senior high schools were randomly sampled to participate in the study and a total of one hundred and thirty-seven (137) students made up of ninety-five (95) in the experimental groups and forty-two (42) in the control group from three intact classes were selected from schools in the Central Region of Ghana. Two mathematics achievement tests, with reliability coefficients of 0.79 and 0.83 were employed by the researcher for data collection. Critical thinking and peer-assessment modules were also developed and used by the researcher for the intervention. The peer-assessment and critical thinking modules were content validated by three experts using percentage of agreement method which yielded 79% and 80% respectively. ANCOVA was used to test the hypotheses at 0.05 level of significance. The findings of the study were that: there was no significant comparative effect of critical thinking and peer-assessment skills training on students' achievement in mathematics. Furthermore, there was no significant interaction effect of gender, age and treatment groups (critical thinking and peer-assessment) on students' achievement in mathematics. Based on the findings, it was recommended that teachers can make use of either peer-assessment or critical thinking strategies in teaching mathematics lessons to bring about the much-needed improvement in students' performance in Mathematics.

Key words: Critical thinking, Peer-assessment, Students achievement, Gender, Age and Core Mathematics

Introduction

Mathematics is a vital tool for the understanding and application of science and technology. The discipline plays the vital role of a precursor and harbinger to the much needed technological and national development, which has become an imperative in the developing nations of the world (Kang'ahi, Indoshi, Okwach & Osodo, 2012). In today's high and ever-increasing technological world, it is important that students, right from childhood, should develop their knowledge and skills in mathematics so that when they grow up they will not have fears about the subject. According to Chen, Liang, Lee and Liao (2011) the National Commission on Excellence in Education spent dollars to provide remedial education programmes for basic skills such as Reading, Writing, Spelling, and Computation. According to the report, many individuals felt that schools were over emphasising reading and computation and not spending adequate time on necessary skills such as comprehension, analysis, solving problems, and drawing conclusions. These skills (comprehension, analysis, solving problems and drawing conclusions) are critical thinking skills which are seemed to be neglected. Critical thinking involves skills by which the students recognise a wide range of subjective analyses and critically evaluate how well each of them might meet their needs and solve problems. Alwehaibi (2012), opined that critical thinking provides the tools for the mind; that people generally need to think through things for both studying and daily life. As thinking skills develop, students gain skills that can be used effectively to reason better through the thinking tasks implicit in future goals achievement.

Peer-assessment, on the hand, is the process by which students mark their colleagues work, critique it and offer suggestions in order to improve their works. The starting point for introducing peer-assessment is for teachers and learning support assistants to model the process that is, acting as role model and explaining and demonstrating how it should be done. For example, showing students how to give constructive feedback, i.e. detailed comments, objective focus, etc. in verbal and writing is necessary. A good way of doing this is to use examples of work from anonymous pupils (e.g. from a previous year or another school), modelling the type of constructive feedback that might be given or providing a list of questions that pupils might ask. The development of critical thinking and peer-assessment skills as desirable educational outcome requires teaching methods which help learners

improve their ability in critical thinking, peer-assessment skills and increase their tendency to use such skills (Karami, Pakmehr & Aghili, 2012). Therefore, the teachers' correct understanding of appropriate teaching methods and effective factors influence many motivational variables of learners such as tendency to think critically.

Today collaborative learning plays an important role between teaching methods. In this method, students cooperate with each other, share the learning experience and thereby, can improve many of their skills and abilities (Chan, 2013). Karami, Pakmehr and Aghili (2012), believed that the output of collaborative learning is far more than competition and individual activities. Alwehaibi (2012), considers fostering dialogue to be part of the method of critical thinking acquisition, because dialogue makes it possible to take the perspective of others into account, which is necessary for 'the assessment of truth claims. Instructional formats in which cooperative learning and dialogue feature are expected to promote the students' active learning and higher-order thinking skills simultaneously (Racionero & Padros, 2010). Garrison (2011) in his book titled 'philosophy for children' introduces an approach which is entirely focused on dialogue and he saw it as a dialogic teaching that improves thinking skills. This skill allows children to have more activity, receives more feedback and enables them to reason based on fact and logic.

Riswanto and Putra (2012), found that through peer-assessment, students enhance their sense of competence and self-worth. Evidence suggests that, when peer-assessment is used effectively it can foster higher-order levels of learning, such as those represented by the upper levels of Bloom's taxonomy and encourage students to develop professional behaviours that require the ability to reconcile multiple perspectives. It encourages students to develop the social skills needed to work in teams, including the ability to provide meaningful feedback and to accept peer critiques (Carlson, Berry & Voltmer, 2005). Zundert, Sluijsmans and Merrienboer (2010), also concluded that teachers and students found the peer-assessment exercise beneficial in terms of developing students' higher-level cognitive thinking and facilitating a deep approach to language learning. Results of several studies in the higher education system have shown the positive effect of collaborative learning method (peer-assessment) on learning skills and high cognitive levels of students (Ebiendele, 2012). According to Tiruneh, Verburgh

and Elen (2014) the kind of teaching method adopted is important for someone to construct correct understanding of critical thinking and learn how to think critically. It could be said that the more the teacher creates opportunities for interaction among learners, the better the opportunities for criticism in students' activities, hence provides a more suitable context for students' critical thinking disposition. Therefore, considering opportunities that collaborative learning compared with individual environment, provides, utilisation of this method by teachers in educational systems is suggested. Students' performances in core mathematics are poor and stakeholders have been wondering how this trend could be solved. As a result, several reasons have been assigned to this abysmal performance of students in the Central Region. Key among the reason's stakeholder attribute to this poor performance is the teaching methods (Cobbinah, 2016). Clearly, the effectiveness of either of the method cannot be doubted but the comparative advantage of one on the other has not been established. Again, an outstanding issue investigated by the researcher was whether gender and age have interaction effects on students' critical thinking and peer-assessment skills in their achievement in mathematics. The findings of most of these studies in the literature reviewed so far were indicative that individual factors were studied and their effects on students' achievement were established but no comparative study for the two skills were done. Therefore, the researcher looked at the comparative effects of critical thinking and peer-assessment skills training and their effects on students' achievement in mathematics as well as the interaction effect of critical thinking, peer-assessment, age and gender. It appears to the best of the researcher's knowledge that not much research of this nature has been done in Ghana. This therefore motivated the researcher to undertake the study to investigate the comparative effects of critical thinking and peer-assessment skills training on Ghanaian senior high school students' achievement in Mathematics.

Purpose of the study

The purposes of the study were to identify the comparative effects of critical thinking and peer-assessment skills training on Ghanaian senior high school students' in mathematics achievement as well as the interaction effect of critical thinking and peer-assessment

skills training on senior high school achievement in mathematics based on gender and age.

Research Hypothesis

1. There is no significant comparative effect of critical thinking skills training and peer assessment skills training on students' achievement in mathematics.
2. There is no significant interaction effect of critical thinking and peer-assessment skills training on students' achievement in mathematics based on age and gender.

Methodology

The research design for this study was a 3x2x2 factorial non-equivalent quasi-experimental design. The independent variables in the study were critical thinking and peer-assessment skills training, while age and gender were intervening variables and achievement in mathematics was the dependent variable. Three intact classes were used for the study. In this design, the dependent variable was measured both before and after the treatment or intervention as depicted below:

Assignment	Group	Pre-test	Treatment	Post-test
(Critical thinking)	1	O_1	X_1 (Gender) (Age)	O_4
(Peer-assessment)	2	O_2	X_2	O_5
(Control)	3	O_3	……	O_6

Figure 1: Diagrammatic Representation of the Experimental Design

Key:

Group 1 = critical thinking, 0_1 = first observation for CT, X_1 = Treatment for CT, 0_4 = second observation for CT.

Group 2 = Peer- assessment, 0_2 = first observation for PA, X_2 = treatment for PA 0_5 = second observation for PA

Group 3 = control, 0_3 = first observation for control, 0_6 = second observation for control

---------- = intact groups no randomization

Gender and age = intervening variables

The diagrammatic representation of the experimental design shown in Figure 1 indicates experimental levels which comprised three (3) groups. These groups were critical thinking skills training (1); Peer –Assessment skills training (2) and the Control (3).

The $O_1 = 0_2 = 0_3$ = pre-test, $O_4 = 0_5 = 0_6$ = Post-test, X_1 = treatment (Critical Thinking) and X_2 = (Peer-Assessment)

The diagrammatic expression of the treatment strategies shown in Figure 1 indicates that the experimental groups 1 and 2 were pretested, after which they underwent experimental treatment and the post-test was administered to them. For the control group, which was group 3, (they received the traditional method of teaching) no treatment was administered but subjects responded to pre-test and post-test instruments. The use of both pre-test and post-test helped to establish, the temporal precedence of the independent variable to the dependent. This gave the researcher more confidence when inferring that the independent variables were responsible for changes in the dependent variable. Secondly, the used of a pre-test allowed the researcher to measure between groups differences before exposure to the intervention. This substantially reduced the threat of selection bias by revealing whether the groups differed on the dependent variable prior to the intervention (Chan, 2013).

Two mathematics achievement tests, with reliability coefficients of 0.79 and 0.83 were developed and employed by the researcher for data collection. Critical thinking and peer-assessment modules were also developed and used by the researcher for the intervention. The modules were content validated by three experts using percentage of agreement method which yielded 79% and 80% for the peer assessment and the critical thinking modules respectively. The 3x2x2 factorial quasi experimental design was used because in a school or natural setting, it may not be possible to randomly assign students to groups since the headmasters/mistresses did not like their classes to be disorganised for the purpose of the research. This design helped in comparing groups against one another, hence it automatically ruled out selection-maturation interaction biases. The critical thinking, peer-assessment and the control group comprised 50, 45 and 42 students respectively. The average age of the critical thinking, peer-assessment and the control groups were respectively 16.8 years, 16.3 years and 16.9 years respectively, whereas the overall average age of students was 16.7 years.

Results and Discussions

Hypothesis one: *There is no significant comparative effect of critical thinking skills training and peer-assessment skills training on students' achievement in mathematics.*

A two-way ANCOVA was carried out to test the comparative effect of critical thinking and peer-assessment skills training of students' achievement in mathematics.

Table 1: ANCOVA Post-test ` Achievement in Mathematics Scores among the Groups

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	16449.747[a]	12	1370.812	13.387	.000**	.564
Intercept	13680.523	1	13680.523	133.601	.000**	.519
Pretest	2413.279	1	2413.279	23.568	.000**	.160
Gender	42.084	1	42.084	.411	.523	.003
Age2	37.287	1	37.287	.364	.547	.003
Group	5169.596	2	2584.798	25.243	.000**	.289
Gender * Age2	1.581	1	1.581	.015	.901	.000
Gender * Group	189.917	2	94.958	.927	.398	.015
Age2 * Group	46.468	2	23.234	.227	.797	.004
Gender * Age2 * Group	233.100	2	116.550	1.138	.324	.018
Error*	12697.377	124	102.398			
Total	533813.000	137				
Corrected Total	29147.124	136				

a. R Squared = .564 (Adjusted R Squared = .522)

* =This means an interaction ** =This means is significant

The result as shown in the Table 1 and with mathematics Achievement Test, F (2,124) = 25.24, p = 0.000, (partial eta squared = 0.29). The result shows a significant difference in achievement in favour of the treatment groups. The eta value indicates that the two treatments contributed equally 29% to the students' achievement in mathematics.

Table 2: Result of Scheffe Post Hoc Test

Group	N	Subset	
		1	2
Control	42	46.40	
Peer Assessment	45		65.07
critical Thinking	50		68.76
Sig.		1.000	.272

The post hoc test results presented in Table 2 shows that though significant differences exist between treatment groups as a subcategory (CT and PA) against the control group, no significant difference was observed in the mean score achievement in the treatment groups (p =1). An indication is that, none of the skills training has a comparative advantage over the other. That is, there is no significant difference in achievement in mathematics between students exposed to critical thinking and those exposed to peer-assessment skills training. Though there was no statistically significant difference in achievement in mathematics in the treatment groups (peer-assessment and critical thinking groups), however, a closer look at the mean scores showed a critical thinking mean score of 68.76 which is higher than the mean score for the peer-assessment group with 65.07. There appears to be similarity between the two interventions, in that in peer-assessment, students were given the opportunity to assess their peers' work with the aid of scoring rubrics.

With these scoring rubrics, students identified the steps involved in the solution of the items and accordingly awarded marks for each step deemed correct and situations where the students had no mark in a step reasons were assigned for it. In awarding the marks students analysed and made inferences which are also skills used in critical thinking. This also supports the findings of Cevik, Haslaman and Cevik (2014) who studied the effect of peer-assessment on problem solving skills of prospective teachers supported by online learning. They found that, the groups involved in study mostly focused on the negative feedback which includes evaluation, explanation and analysis as well as suggestion type feedback (revision and detailed revision). To them the groups mostly ignored the positive evaluation, explanation and analysis. These groups one could say that they were making use of critical thinking skills in their learning. Evidence also suggests that, when peer-assessment is used effectively, it can foster higher order

levels of learning such as those represented by the upper levels of Bloom's taxonomy and encourage students to develop professional behaviours that require the ability to reconcile multiple perspectives (Carlson et al., 2005).Again Zundert et.al., (2010) concluded that teachers and students found peer-assessment exercise beneficial in terms of developing students higher level thinking. This implies that students critical thinking skills can be acquired through peer-assessment skills. However, Alwehaibi (2012) believed that fostering dialogue is a way of critical thinking acquisition, because dialogue makes it possible to take the perspective of others into account, which is necessary for 'the assessment of truth claims. Therefore, there seem to be a thin line between the two skills. Though research has indicated the effectiveness of the two skills training for improving students' performance no literature has reported their comparative effectiveness or advantage of either. However, this study has reported no comparative effects of the two interventions. Probably, the slight mean score increases in the critical thinking (CT) skills training as against the peer-assessment mean score was probably due to an increased in the knowledge in mathematics by students who received that training (CT).

Hypothesis 2*: There is no significant interaction effect of critical thinking and peer-assessment skills training on students' achievement in mathematics based on of age and gender*

The results form Table 1 again shows that, there was no significant interaction effect of Group and Gender F (2, 124) = .927, p = 0.398 with a minimum effect size (partial eta squared = 0.015). This indicates that there is no significant difference in the effect of gender on the achievement in mathematics in the treatment groups. This eta value means that the interaction effect of gender on group contributes 1.5% to the students' achievement in mathematics. On Group and Age there was no significant effect, F (2, 124) = .227, p = .797 with effect size of 0.004. This means that there is no significant difference in the effect of age on the achievement in mathematics in the treatment groups. On Gender and Age F (2, 124) = .015 p= .901 with effect size = .000). This also indicates that there is no significant difference in the effect of age on achievement in mathematics for both male and female.

Similarly, the interaction effect of gender and age contribute 0.0% and group and age contribute 0.4% respectively to students' achievement in mathematics. A multiple interaction effect of

Group, Gender and Age also showed no significant effect, F (2,124) = 1.138, p = 0.324 with effect size of 0. 018. This indicates that there is no significant difference in the effect of gender and age on achievement in mathematics in the treatment group. An eta value of 0.018 indicates the combine effect of, group, age and gender contributing 1.8% to students' achievement in mathematics. The results also indicate that for gender and age the two groups showed no significant difference in the two interventions and that designing such interventions one may not necessarily consider gender and age of the participants. The results in this study further suggest that for gender the two groups (male and female students) showed no significant interaction effect in the two interventions. Again, for age the result suggests that the two groups of ages (14- 16) years and 17- 19 years) showed no significant interaction effect on peer-assessment and critical thinking skills training of students. Hence there is no interaction effects on the treatments based on gender and age. The fact is that whether male or female and young or old students' responses to the two interventions indicated that they were probably not matters to consider. Thus, designing such interventions one may not necessarily consider gender and age differences of the participants. It suggests again that it is the intervention strategies which should be well packaged to bring about the needed academic achievement change in the students and probably not students being male or female and young or old. Even though critical thinking (CT) and peer- assessment (PA) as factors influencing students' academic achievement has been reported in the literature, the interaction effect of peer- assessment and critical thinking based on age and gender has not yet been reported in the literature was found in this study to have no interaction effects. This result probably might have arisen due to the enthusiasm exhibited by both groups of students to learn the skills being taught them.

Conclusion and Recommendations

The two skills training have a high- activity-based student's participation which brings effectiveness in teaching. The result also showed that critical thinking and peer-assessment could be used to improve senior high school students' achievement in mathematics irrespective of gender and age. Though age and gender difference could not be found to have an effect on students' achievement in this study, teachers should not ignore their importance in contributing to the

overall students' success. That teaching method could be at the root of students' failure in mathematics; however, their ages or gender may not be considered in choosing either critical thinking or peer-assessment training for their learning improvement. Based on the findings, the following recommendations were made: Critical thinking and peer-assessment skills training modules can be invaluable short-term tools which policy makers and implementers can make use of in the teacher education programme to improve the quality of teacher training and to enhance the teaching of critical thinking and peer-assessment skills in our schools irrespective of age and gender. Teachers should make use of any of the two teaching skills which they feel comfortable, knowledgeable and very effective in, during teaching to impact positively on students' performance.

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