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Influence of Collaborative Learning on the Conceptualization of Ideas, Application of Acquired Ideas, and Academic Performance of Undergraduates

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Abstract

An active engagement involving undergraduates working together to solve problems is unrestrained nowadays. This study presents the influence of collaborative learning on the first two cognitive components of critical thinking (i.e. conceptualization of ideas and application of acquired ideas) and the academic performance of undergraduates in three Departments at the Federal University of Technology Akure (FUTA), Nigeria. A reliable and valid instrument was developed and presented in this report to measure the first two cognitive components of critical thinking (CT), a major innovation agent. A random selection of 318 students from the Departments of Mathematical Sciences, Computer Science and Statistics were considered to respond to the instrument. Kruskal-Wallis H test, Independent t-test, and One-way Analysis of Variance (ANOVA) were adopted to analyse information extracted from the questionnaires. It is worth concluding that male students applied acquired ideas/knowledge more than their female counterparts. In contrast, their ability to conceptualize ideas and academic performance is the same. Better ability to apply acquired ideas and improvement in the academic performance of the undergraduates are guaranteed at average participation in collaborative learning.

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Introduction

Knowledge-driven has turned the world into a complex and challenging global village. The world can be regarded as dynamic, so it cannot be in equilibrium even for a nanosecond. New problems, discoveries, technologies, and inventions are facts that support this claim. Thus, the ability to think critically about the masses is one of the essential tools in coping with the world's dynamism. Historically, critical thinking emerged during the

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seventies and eighties as an alternative and remedy for reproductive learning (i.e., learning involving memorizing and reproducing facts without proper understanding). In addition to Montuori, 2012), critical thinking is not only helpful in acquiring good grades in school alone. However, it is also required at workplaces to face the challenges of changing situations in the modern world. Many authors have defined critical thinking as necessary for achieving set goals. (Ennis, 1989) (Ennis, 1987) defines critical thinking as reasonable reflective thinking, which is highly focused on deciding what to believe or do. Thus, critical thinking can be regarded as a criterion which can be used to evaluate written or verbal information. Moreover, the conceptualization of an idea can be referred to as the early stage of critical thinking. This is supported by the results of Ennis (Ennis, 1987), Baron (Baron, 1985), and Mcpeck (McPeck, 1981), in which critical thinking is viewed as a skill, a set of skills, a mental procedure, or rational thinking. Engaging in relevant activities and studies can develop and improve critical thinking. (Facione, 1990) explained that inference, self-regulation, evaluation, explanation, analysis, and interpretation are six cognitive skills that can lead to demonstrating critical thinking. (Knustson, 2012) defines critical thinking as applying knowledge and intelligence in making decisions and giving opinions on issues. (Chukwuyenum, 2013) remarked that this particular form of thinking could be described as a tool used to solve problems because the process of establishing the thinking to make reliable and valid decisions requires logical reasoning, interpretation, analyses, and evaluation of information. Recently, (Butler *et al*., 2017) compared the significance of intelligence and real-world outcomes. It was concluded that critical thinking could be referred to as a predictor of real-world outcomes despite intelligence determining various life outcomes.

From these definitions, it can be deduced that ability to apply acquired knowledge and evaluation of consulted materials indicate one's level of critical thinking. More generally, it is discovered in (Paul, 2007) that critical thinking is a mode of thinking, a tool that contributes to improving the quality of thinking about any field of study by skillfully analyzing, accessing and reconstructing meaningful thoughts. It is widely known that good judgment with a positive outcome is a function of a thinking process. This fact led (Halpern, 2003) to conclude that critical thinking is a powerful tool in making an effective and accurate judgment as it involves using cognitive skills to enhance the probability of a desirable outcome. Kek and (Kek *et al*., 2013) and McLaren (McLaren, 1997) remarked that many scholars have opined that students should strive to attain critical thinking abilities to help them make objective judgments and decisions when facing controversial technological issues. According to (Norris, 1985) reflection on the effects of technology development, the ability to weigh diverse values objectively, and the development or selection of appropriate solutions to problems are all characteristics of good critical thinkers. (Smith, 1990) maintained that practical critical thinking could be regarded as a particular type of thinking which involves the capabilities to engage in rational consideration, analysis of data, an evolution of thought, inductive reasoning and verification of results. Similarly, (Fisher, 2001) came up with a conclusive statement that capabilities for determining the message behind different types of technical information and analyzing this information are found to be functions of sound judgment and logical thinking. A deduction from the work of (Lau, 2011) indicates that one's ability to think clearly, rationally, and engage in reflective and independent thinking indicates a high level of critical thinking. Ability to comprehend the logical connection between notions, to identify, discover, construct and evaluate arguments, to test for the consistency and validity of arguments, to provide systematic solutions to problems, and to reflect and justify one's beliefs/values are all manifestations of critical thinking. Consequent to all these manifestations, a rational individual may like to know if offering specific secondary school courses (i.e., mathematics and further mathematics) enhances the development of critical thinking.

Cognitive domain of individual deals with the development of intellectual skills and abilities. A good number of survey research has been carried out to deliberate on enhancing and developing the cognitive aspect of critical thinking. In all these reports, the contribution of Bloom Benjamine on the cognitive domain is held in high esteem. Bloom's Taxonomy of Educational Objectives subdivides the academic skills that students might need into six different hierarchical categories: knowledge, understanding, application, analysis, synthesis and evaluation Bloom; (Eisner *et al*., 1972) and

Nwana (Nwana, 1981). Thus, in developing critical thinking, memorization of facts, figures, and some basic concepts (knowledge) must be done, followed by comprehending and illustrating the facts (understanding). Consequently, the generalization of the facts to other contexts and situations (application) shows the usefulness and importance of these facts. Understanding the existence of the facts and their components determines one's ability to analyze. Although, making connections between different elements of the facts (synthesis) is found to be in higher rank than analysis of the facts. Meanwhile, this level is lower than the ability to judge or ascertain the quality of information (evaluation). The use of Bloom's Taxonomy in teaching critical thinking has been found to enhance students' critical thinking levels in the survey research conducted by Nancy and Ruth (Nancy *et al.*, 2008) Kelly (Kelly, 2009) maintained that traditional examinations do not enhance critical thinking as they emphasize giving back exactly what has been taught (cramming) rather than conceptualizing and applying the acquired knowledge. Moreover, the mode of testing students' performance should be changed from retention-based tests to critical inquiry to improve students' critical thinking levels. Survey research by Kyounga (Kyoungna *et al.*, 2013) revealed that active learning (i.e. class presentation and group work) enhances critical thinking. A good relationship between learning styles, critical thinking and academic performance of students was discovered by Zhore (Zhore *et al.*, 2014). It was concluded that students who possess active learning styles are good critical thinkers and have excellent academic performance.

Mathematics's role in developing students' critical thinking skills at various educational levels must be addressed. Mathematics is a discipline that provides students with problem-solving skills and forms the bedrock for all other disciplines. Konstatinos and Eleni (Konstantinos *et al.*, 2013) discovered that secondary school students could develop critical thinking skills by solving interdisciplinary statistics and mathematics (i.e. Algebra) problems. Meanwhile, such a golden opportunity which would have led to a continuous and systematic development of critical thinking, has been restrained from the people of Greece. As pointed out by Hinchley (Hinchley, 1931) the knowledge of algebra, pure and applied calculus, descriptive geometry, trigonometry, and physical and chemical change rates are prerequisites for better understanding and investigating practical problems. The study conducted by McCarron and Burstein (McCarron *et al.*, 2017) revealed that mathematics had been the prerequisite to introductory financial accounting since its inception as it improves the probability of obtaining a good grade in introductory accounting. Mathematics can be seen as a set of guidelines that helps the general public develop problem-solving, thinking, reasoning, numeracy skills, and economy of thought, according to Animasaun and Abegunrin (Animasaun *et al.*, 2016). In the article, it is also remarked that the low level of problem-solving skills of people could be attributed to their low passion for mathematics or inability to comprehend the fundamental aspects of mathematics. Although this claim is left for criticism, at least it established that problem-solving skills depend partially, if not totally, on the fundamental knowledge of mathematics. The justification for this is plausible, as mathematics is being taught right from the lowest level of education. It is essential to understand the connection between undergraduate students' conceptualization, application, and academic achievement (CGPA), given the importance of mathematics in developing students' critical thinking and problem-solving skills. Investigating the connection between undergraduate students' academic success and the availability of Further Mathematics in secondary schools is vital.

Leach (Leach, 2011) focused on the significant shift in the educational system in the United States of America owing to its effects on critical thinking, recitation, and core-content memorization. In the study, five dimensions of critical thinking of 1,455 graduates in the 2009 - 2010 academic session were measured using The California Critical Thinking Skills Test. As a matter of fact, there is no globally accepted method of measuring critical thinking. However, many attempts have been made to measure critical thinking. Among these attempts is the work of Ahrash (Ahrash *et al.*, 2006). In the article, a questionnaire which is based on Bloom's taxonomy of educational objectives (cognitive domain) is presented, where each of the levels in the taxonomy is graded based on their rank in the cognitive domain. Kelly (Kelly, 2009) argued that measuring critical thinking by using a multiple-choice response format questionnaire fails to give reasons for choosing an option the participants and does not reflect on their ability to think critically under unprompted situations, while a combination of multiple-choice and open-ended questionnaires allows for better measurement of critical thinking of respondents. However, open-ended questionnaires are characterized by some shortcomings which limit their effectiveness and usage; among these are time-consuming, difficulty in filling in the information required, misinterpretation of the information provided due to the inability of the respondents to express themselves clearly or the use of different writing styles, difficulty in classification and quantification of the responses. Above all, the Watson-Glaser Critical Thinking Appraisal is discovered to be the most appropriate method of measuring critical thinking. Goodwin Watson and Edward Glaser designed the Watson-Glaser Critical Thinking Appraisal (W-GCTA). It measures the critical thinking of the target population by asking questions relating to critical skills necessary for the clear, structured and well-reasoned presentation of ideas suitable to convince others of one's arguments. These questions were prepared to measure the ability of respondents to make correct inferences, recognize assumptions, make deductions, make conclusive statements, and interpret and evaluate arguments; see Watson (Watson, 1980), Watson and Glaser (Watson *et al*., 1980). This is apparent in the conclusive statement of Helmstader (Helmstadter, 1965) also stated by Pike (Pike, 1996) as "The Watson-Glaser Critical Thinking Appraisal represents a highly professional attempt to measure important characteristics. And, while there may be some flaws in the test, it is doubtful whether a significantly better measure will be found until there is a major breakthrough either in test technology or in our understanding of the thinking process".

In this survey research, critical thinking is viewed as the ability to conceptualize ideas (i.e. pulling ideas together to form a concept and arranging them into patterns which show their relationship), apply ideas (i.e. uses of acquired knowledge in solving real-life problems), analyze information or data (which involves the breaking down of information or data into its parts for better understanding), synthesize ideas (involves the building up ideas or raw facts to form a new knowledge) and evaluate thoughts (involves judging a piece of information based on specific criteria). This is realistic because establishing a higher level of critical thinking skills is based on the previous lower level. Specifically, the effects of gender difference, offering of further mathematics in secondary schools, collaborative learning and the ability to identify a real-life problem are investigated on the conceptualization of acquired ideas, application of ideas, and academic performance of undergraduates.

Research Questions

In this survey research, the following research questions were developed:

- What are the differences in the conceptualization of ideas, application of acquired ideas, prior knowledge of advanced Mathematics, and academic performance between male and female undergraduate students?
- Is there any significant difference between male and female undergraduates in their academic performance, conceptualization, and application of acquired ideas?
- What are the differences between collaborative learning, conceptualization of ideas, application of ideas and academic performance of undergraduates?
- Is there any significant difference in the academic performance, conceptualization of ideas and application of acquired ideas of undergraduates with low, medium and high ability to identify a real-life problem?

Essence and Objectives of the Study

Conceptualization and application of acquired ideas of undergraduates are very crucial as they help to solve real-life problems, transform ideas to concept, apply ideas, and improve the economy of the nation in general. However, development of a cognitive component of critical thinking of Nigerians is needed to solve the problems ahead of the nation. Ability to conceptualize ideas goes a long way in understanding the rudiments of real-life problems, thus prepares one’s mind for suitable and feasible solutions of the problems. Moreover, conceptualization of ideas is a prerequisite for application of ideas and forms an integral part of the academic performance of students. The academic performance of students taking mathematics courses has been steadily declining, which negatively impacts the nation's technological advancement, claims Fafunwa (Fafunwa, 1980). Adeyemi (Adeyemi, 2011) stated that a student's academic standing at any particular time is the ideal way to describe academic performance. This academic status depends on the student's grades in a particular course or set of courses. However, Mathematics is the rudiment of all other science-related courses and it is also applied to certain problems in other fields such as engineering, management, arts, and humanities etc. Thus, the aim of this study is investigate the influence of collaborative learning on the cognitive components of critical thinking (i.e. conceptualization of ideas and application of acquired ideas) and academic performance of the undergraduate students.

Therefore, it is investigated how gender differences, prior knowledge of advanced mathematics, conceptualization and application of learned knowledge, and academic performance of undergraduate students of mathematical sciences, statistics, and computer science at the Federal University of Technology, Akure, Ondo State, Nigeria. One of the mandates of National Mathematical Center Abuja, Nigeria is the training and development of high-level personnel (citizens) in Mathematical Sciences. Meanwhile, ability to think critically is one of the most valued learning goals and embedded rewards of studying mathematics. This survey research will help the organization to acquire a better understanding of the concept (conceptualization and application of acquired ideas). This study is also significant to the Deputy Vice-Chancellor (Academics) of FUTA and all other universities in general, as it will help them to know the relationships between Mathematics, cognitive aspect of critical thinking and academic performance of students. Parents will also find this study to be useful as it emphasizes on the contribution of further-mathematics to the development of critical thinking of their children. Finally, this study will also help undergraduates who aim to develop their thinking skills and graduate with excellent result.

Research Methodology

The main purpose of this study is to investigate the influence of collaborative learning on the cognitive components of critical thinking (i.e. conceptualization of ideas and application of acquired ideas) and the academic performance of undergraduate students. To accomplish this, survey research was carried out within six months. A questionnaire survey (one of the classifications of a scheme of survey research) was adopted, which serves as the major tool for data collection. The questions were developed based on Bloom’s taxonomy of educational objectives, grouping the first two entries (knowledge and understanding) as conceptualization of ideas. A structured or fixed response questionnaire was used with graded options.

Population of the Study

The Federal University of Technology Akure, Ondo state consists of forty-six departments emerging from seven different schools. Specifically, the population of this research comprise the Departments of Mathematical Sciences (MTS), Computer Science (CSC) and Statistics (STA), all of which are under the School of Sciences. Students in these three departments were considered suitable for the research because they are science students and offered advanced level Mathematics courses in the first and second years. The target population is composed of over 400 students from 300 level to 500 level, and each of them offers advanced level Mathematics courses from their first year to the final year.

Sample and Sampling Technique

Out of the target population, a sample of 318 students from the three departments was examined. This sample size was considered because examining the whole target population is tedious, impractical, and time-consuming. Some students were not available during the time of distribution of questionnaires while it was impossible to get the support of some students. In addition, to obtain a perfect sample which represents the target population and provides a better understanding of the larger population, random sampling was adopted. In summary, a random sample of 318 students was used in this survey research, 112 from Mathematical Sciences, 62 from Computer Science and 144 from Statistics.

Research Instrument

An observational technique, questionnaire and interview are some of the basic ways of collecting data. The choice of research instrument depends largely on the nature of research, type of data and the level of accuracy of the research findings. Thus, research instrument is one of the factors affecting the reliability of research accuracy and reliability of research findings. In order to avoid usability problems (i.e. problem with interpretation, problem with scoring/interpretation, and problem with administration), a new fixed response questionnaire was developed and used for data collection. However, there exist no perfect instrument for measuring critical thinking; see Pike (Pike, 1996). Following Ku (Ku, 2009) the adoption of questionnaire in this research study was due to the fact that it is economical (with regards to time and cost), reduces the stress and influence of researchers, and most importantly, the results obtained are easily comparable and interpreted. The choice of fixed response or structured type of questionnaire was considered because the respondents are limited to response options designed to give appropriate answers to the research questions and provide justifications for the acceptance or rejection of research hypotheses. The questionnaire consists of five items under conceptualization of ideas and another five items under the application of ideas which are fashioned to get a reliable and consistent response from respondents, and also to establish the objectives of the research.

Administration of Instrument

One strategy for achieving a respectable level of questionnaire delivery and return is personal administration with the on-the-spot collection. This method is adopted for its high efficacy and efficiency level. It allows researchers to shed light on the ambiguities that may arise during the administration of the questionnaire. Most importantly, misinterpretations and misconceptions are clarified on the spot of questionnaire administration. The researcher tried to avoid ingenuity in the respondents' responses due to personal influence, coarseness or persuasion.

Data Collection Procedure

The questionnaires were distributed to the selected students to fill. There was no barrier in administering the questionnaire since the target population consists of literate individuals. Bloom's taxonomy of educational objectives was used as the basis for student's level of critical thinking. The sensitive part of the data used in this study is CGPA and it was obtained from examination officer of each department in consideration. The CGPA of the respondents was used to grade their respective academic performance. The composite scores for the conceptualization and applications skills were computed based on the options chosen by the respondents.

Psychometric Properties of the Data

The validity and reliability of an instrument are referred to as psychometric properties. A copy of the questionnaire (instrument) was given to three researchers in educational research, two lecturers in the statistics Department and a lecturer in the General Studies Department for a thorough examination and revision before expert validation was considered. Following the report of Garca (Garca *et al.*, 2009). , both construct and content validity of the instrument were established. These two methods of validation were complemented by using trial and pilot testing. In this study, the test-retest method was considered to verify the instrument's reliability. The instrument was administered to 16 respondents from the population on two different occasions. In order to ensure that the memory of each of the sixteen respondents who were chosen for the first test did not influence their responses in the second and to avoid some of the difficulties (i.e. very long interval -variations and too short interval-learning effect) attached to this technique, the time between the two administrations was 14 days. The two replies from the two questionnaire sessions were correlated with one another. The coefficient of stability (i.e. a positive correlation) was estimated as 0.67. An internal consistency analysis for the two subscales was estimated by computing Cronbach's alpha for items on the conceptualization of ideas and application of acquired ideas as 0.61 and 0.68. It is worth noticing from the analysis that the removal of items "*When I try to pull ideas together to form a concept*" and "When I try to apply formulas, procedures, or principles to a new problem, assignment, or situation that seems unfamiliar, I can use them accurately." would lead to an improvement in the internal consistency.

Data Analysis

The extracted data from the questionnaire were analyzed using Statistical Software Package for Social Sciences (SPSS Version 21). Item analysis of the data extracted from 239 males (75.2%) and 78 females (24.5%) was carried out using descriptive statistics-frequencies package. Out of the 318 randomly selected participants, 32.1% offered further mathematics in secondary school while 67.6% did not offer the subject. The outcome of the item analysis shows that 44 (13.8%) of the respondents have low likeness for collaborative learning, 146 (45.9%) declared medium likeness while 126 (39.6%) have high likeness for reading with friends (collaborative learning). It is revealed that students that could sometimes apply acquired/ conceptualized ideas to a new problem constitute the greatest percentage, followed by those that can always apply this idea, then by those that rarely do and then those that do not have this ability at all; for more information see Tables 1. It is therefore easily concluded that the ability to conceptualize ideas is directly proportional in nature to the ability to apply these acquired ideas accurately. It is worth noticing that a student that can conceptualize an idea has the ability to apply that idea. Consequently, an attempt was made to test for the normality of composite scores on conceptualization, application, and academic performance of the respondents (CGPA).

Table 1: Analysis of responses to conceptualization-related items

	Descriptive Statistics				
		Not all (%)	**Very rare (%)**	**Somet-imes (%)**	**Always (%)**
1	I can pull ideas together to form a concept.	2.2	9.7	60.1	27.4
2	When I try to pull ideas together to form a concept: I cannot capture the ideas (2.8%); I only see the ideas (9.7%); I see the ideas better than the concept (49.7%); I see the concept (36.2%).				
3	When I try to pull ideas together to form a concept, I arrange the ideas into a pattern.	2.8	11.9	60.1	24.2
4	When I try to pull ideas together to form a concept, I arrange the ideas into a pattern that includes clear relationships.	2.5	11.9	57.5	27
5	When I try to pull ideas together to form a concept, I link the ideas together perfectly and explain the relationships.	1.3	10.1	61.3	26.4
6	I can apply formulas, procedures, or principles to a new problem, assignment, or situation.	3.8	13.5	56	25.8
7	When I try to apply formulas, procedures, or principles to a new problem, assignment, or situation I have trouble thinking of the right formula/concept to use.	11.9	59.7	22.3	4.1

Table 2 a: Results of group statistics independent t-test on the analysis to ascertain if there exist differences the three dependent variables between male and female

Dependent Variables	Groups	N	Mean	Standard Deviation	Std. Error Mean
Composite score of responses to	Male	237	10.77	2.353	0.153
items on conceptualization	Female	78	10.15	2.778	0.315
Composite score of responses to	Male	236	8.87	2.225	0.145
items on application	Female	78	8.24	2.071	0.235
Academic performance	Male	175	3.1831	0.8178	0.06182
of students	Female	57	3.156	0.6935	0.09186

In this research, Normal Q-Q Plots were used in this study to test for the normality of the extracted data. It was deduced that the composite scores on conceptualization, application and academic performance of respondents are normally distributed. The analysis of differences between male and female students in the mean of composite scores on conceptualization, application of ideas and academic performance after using independent t-test and homogeneity of variances are presented in Tables 2a and Tables 2b. The result reveals that sig = 0.379 > 0.05, sig = 0.632 >0.05 and sig = 0.068 > 0.05; see Tables 2b. The implication of these results is that the variability in the two conditions is the same (i.e. equal variances assumed). This study found that the mean of composite scores to items on conceptualization of 237 males is greater than that of 78 females (i.e. 10.77 > 10.15), the mean of composite scores to items on application of 236 males is greater than that of 78 females (i.e 8.87 > 8.24), while the mean of academic performance of 175 male students is greater than that of 57 female students (i.e. 3.1831 > 3.1560). The null hypothesis which states that there is no significant difference between male and female respondents in the means of composite scores on conceptualization of ideas and academic performance of selected students was accepted. This conclusion is based on the fact that t(313) = 1.909, p = 0.057 and t(230) = 0.226, p = 0.822. Meanwhile, it was valid to conclude that there exist a significant difference between male and female in their ability to apply acquired ideas; t(312) = 2.188 p = 0.029.

Table 2b: Equality of variances of responses to the three dependent variables for two groups of gender and group statistics for independent t-test

Dependent Variables	Equality of Variances	F	Sig.	t	df	Sig. (2-tailed)
Composite score of responses to items on conceptualization	Equal variances assumed	0.775	0.379	1.909	313	0.057
	Equal variances not assumed			1.756	115.546	0.082
Composite score of responses to items on application	Equal variances assumed	0.229	0.632	2.188	312	0.029
	Equal variances not assumed			2.268	140.218	0.025
Academic performance of students	Equal variances assumed	3.366	0.068	0.226	230	0.822
	Equal variances not assumed			0.246	110.895	0.807

Table 3a: Results of group statistics independent t-test on the mean, standard deviation, and Std. Error Meane

Dependent Variables	Groups	N	Mean	Standard Deviation	Std. Error Mean
Composite score of responses to	No	101	10.57	2.483	0.247
items on conceptualization	Yes	214	10.66	2.422	0.166
Composite score of responses to	No	100	8.51	2.303	0.23
items on application	Yes	214	8.83	2.126	0.145
Academic performance	No	72	2.9872	0.80858	0.09529
of students	Yes	160	3.2687	0.75523	0.05971

The outcome of the analysis of differences between students who offered advanced mathematics subject (i.e. further-mathematics) when they were in secondary school and those who did not in (a) their ability to conceptualize ideas, (b) their ability to apply acquired ideas, and (c) academic performance is presented in Tables 3a and Tables 3b. It is worth observing that the variability in the two conditions is the same, hence, equal variance for each analysis is assumed due to the fact that sig = 0.172 > 0.05, sig = 0.484 > 0.05, and sig = 0.549 > 0.05. This study demonstrates that 214 respondents who offered extra mathematics in secondary school had mean composite scores to items on the conception that were higher than those of 101 pupils who did not (i.e. 10.66 > 10.57). It is also revealed that the mean of composite scores to items on the application of 214 respondents who actively participated in further mathematics class in secondary school is greater than that of 101 students who avoided the classes (i.e. 8.83 > 8.51). However, it was also found that 160 undergraduate students who took extra mathematics in secondary school performed better academically than 72 pupils who did not take the course (i.e. 3.2687 > 2.9872). The null hypothesis which states that there is no significant difference between students who offered further-mathematics in secondary school and who did not in the means of composite scores on the conceptualization of ideas and application of acquired ideas of selected students was accepted. This conclusion is based on the fact that t(313) = -0.303, p = 0.762 and t(312) = -1.199, p = 0.231. Meanwhile, it is valid to conclude that there exists a significant difference between this group in their academic performance since t(230) = -2.569 and p = 0.011; see Tables 3b.

Table 3b: Equality of variances of responses to the three dependent variables for two groups on offering of further mathematics and group statistics for independent t-test

Dependent Variables	Equality of Variances	F	Sig.	t	df	Sig. (2-tailed)
Composite score of responses to items on conceptualization	Equal variances assumed	0.172	0.678	-0.303	313	0.762
	Equal variances not assumed			-0.3	191.815	0.764
Composite score of responses to items on application	Equal variances assumed	0.484	0.487	-1.199	312	0.231
	Equal variances not assumed			-1.165	180.263	0.246
Academic performance of students	Equal variances assumed	0.549	0.46	-2.569	230	0.011
	Equal variances not assumed			-2.503	128.824	0.014

Table 4 displays the results of the ANOVA analysis comparing the means of the responses to questions on conceptualization skills, application skills, and academic achievement from a group of students with low, medium, and high levels of personal interest in collaborative learning. The null hypothesis, according to which there is no statistically significant difference between the means of the composite scores of responses to questions on conceptualization and application of ideas by undergraduate students with low, medium, and high likeness for collaborative learning, is a valid one to accept; sig: = 0.540 and sig: = 0.063; see Table 5. However, there exists a statistically significant difference in the means of the CGPA (academic performance) of undergraduate students selected from the three groups of likeness for collaborative learning. The result of test of homogeneity of variances indicates that the variation in the variances are the same; see Table 6. Hence the Tukey HSD was considered to further explore Post-Hoc multiple comparisons. It can be deduced from the Post-Hoc multiple comparison (Table 7) that:

- the academic performance of the selected undergraduate students with medium likeness for collaborative learning (3.3518±0.72048; p = .001) is found to be statistically significantly higher than that of students with high likeness (2.9516 ± 0.80834; p = .001); whereas there is no statistical significant difference between the academic performance of undergraduate students with low likeness for collaborative learning (3.2710 ± 0.73613; p = .862) and those with medium likeness.

- the academic performance of the selected undergraduate students with high likeness for collaborative learning (2.9516±0.80834; p = .001) is observed to be statistically significantly lower when compared to those with medium likeness (3.3518±0.72048; p=.001); whereas there is no statistically significant difference between the academic performance of undergraduate students with low likeness for collaborative learning (3.2710 ± 0.73613; p = .107) and those with high likeness.

Table 4: Results of ANOVA and multiple comparisons on the association between personal likeness for collaborative learning and composite scores of replies to items on conceptualization and application abilities and academic success

Descriptive								
	`	N	Mean	Std. deviation	Std. error	95% confidence interval for mean	
						Lower bound	Upper bound
Dependent variable 1:	Low	44	10.3	2.733	0.412	9.46	11.13
Composite score of	Medium	144	10.54	2.362	0.197	10.15	10.93
responses to on n	High	126	10.75	2.5	0.223	10.31	11.19
conceptualization	Total	314	10.59	2.469	0.139	10.32	10.87
Dependent variable 2:	Low	44	8.55	2.406	0.363	7.81	9.28
Composite score of	Medium	144	9.01	2.253	0.188	8.64	9.36
responses to items	High	125	8.4	1.996	0.179	8.05	8.75
on application	Total	313	8.7	2.189	0.124	8.46	8.95
Dependent variable 3:	Low	31	3.271	0.73613	0.13221	3.001	3.541
Academic performance	Medium	104	3.3518	0.72048	0.07065	3.2117	3.492
of students	High	96	2.9516	0.80834	0.0825	2.7878	3.1153
	Total	231	3.1746	0.78054	0.05136	3.0734	3.2758

Table 5: Results of ANOVA and multiple comparisons on the correlation between academic achievement and personal propensity for collaborative learning and composite response score to conceptualization and application skills questions.

ANOVA						
Dependent Variables	Equality of Variances	Sum of squares	df	Mean square	F	Sig.
Dependent variable 1: Composite score of responses to items on conceptualization	Between groups	7.54	2	3.77	0.617	0.54
	Within Groups	1900.282	311	6.11		
	Total	1907.822	313			
Dependent variable 2: Composite score of responses to items on application	Between groups	26.486	2	13.243	2.795	0.063
	Within Groups	1468.881	310	4.738		
	Total	1495.367	312			
Dependent variable 3: Academic performance of students	Between groups	8.33	2	4.165	7.206	0.001
	Within Groups	131.797	228	0.578		
	Total	140.127	230			

Table 6: Results of ANOVA and multiple comparisons on the association between personal likeness for collaborative learning and composite scores of responses to items on conceptualization and application skills and academic performance

Test of homogeneity of variances				
	Levene statistic	**df1**	**df2**	**Sig.**
Dependent variable 1: Composite score of responses to items on conceptualization	0.336	2	311	0.715
Dependent variable 2: Composite score of responses to items on application	0.433	2	310	0.649
Dependent variable 3: Academic performance of students	0.459	2	228	0.633

Table 7: Results of an ANOVA and multiple comparisons on the association between personal likeness for collaborative learning and composite scores of replies to items on conceptualization and application abilities and academic success

Multiple comparisons								
Dependent variable				**Mean diff. dependent variable (I-J)**	**Std. error**	**Sig.**	**95% confidence interval**	
							Lower bound	**Upper bound**
Dependent variable 1: Composite score of responses to items on conceptualization	Tukey HSD	Low	Medium	-0.246	0.426	0.832	-1.25	0.76
			High	-0.459	0.433	0.54	-1.48	0.56
		Medium	Low	0.246	0.426	0.832	-0.76	1.25
			High	-0.212	0.302	0.761	-0.92	0.5
		High	Low	0.459	0.433	0.54	-0.56	1.48
			Medium	0.212	0.302	0.761	-0.5	0.92
Dependent variable 2: Composite score of responses to items on application	Tukey HSD	Low	Medium	-0.468	0.375	0.425	-1.35	0.41
			High	0.145	0.382	0.923	-0.75	1.04
		Medium	Low	0.468	0.375	0.425	-0.41	1.35
			High	0.614	0.266	0.056	-0.01	1.24
		High	Low	-0.145	0.382	0.923	-1.04	0.75
			Medium	-0.614	0.266	0.056	-1.24	0.01
Dependent variable 3: Academic performance of students	Tukey HSD	Low	Medium	-0.0807	0.15558	0.862	-0.4479	0.2862
			High	0.31941	0.15706	0.107	-0.0511	0.6899
		Medium	Low	0.08087	0.15558	0.862	-0.2862	0.4479
			High	0.40027*	0.10761	0.001	0.1464	0.6541
		High	Low	-0.31941	0.15706	0.107	-0.6899	0.0511
			Medium	-0.40027*	0.10761	0.001	-0.6541	-0.1464

*The mean difference is significant at the 0.05 level.

Table 8: An overview of the descriptive statistics, ANOVA findings, and multiple comparisons on the correlation between academic success and the capacity to recognize a real-world problem and the overall scores on the conceptualization and application skills items

Descriptive							
	`	N	Mean	Std. deviation	Std. error	95% confidence interval for mean	
						Lower bound	Upper bound
Dependent variable 1:	Low	13	8.38	2.534	0.703	6.85	9.92
Composite score of	Medium	188	10.04	2.428	0.177	9.69	10.39
conceptualization	High	112	11.81	1.984	0.188	11.44	12.18
	Total	313	10.60	2.471	0.140	10.33	10.88
Dependent variable 2:	Low	13	7.69	1.548	0.429	6.76	8.63
Composite score of	Medium	187	8.60	2.025	0.148	8.31	8.89
responses to items	High	112	9.03	2.484	0.235	8.56	9.49
on application	Total	312	8.71	2.199	0.124	8.47	8.96
Dependent variable 3:	Low	11	3.2500	0.89723	0.27052	2.6472	3.8528
Academic performance	Medium	139	3.1599	0.75550	0.06408	3.0332	3.2866
of students	High	80	3.2100	0.83842	0.09374	3.0234	3.3966
	Total	230	3.1817	0.78893	0.05202	3.0792	3.2842

Table 9: Overview of the descriptive statistics, ANOVA findings, and multiple comparisons on the correlation between academic achievement and the ability to recognize a real-world problem and the overall score on the conceptualization and application skills section of the test

ANOVA						
Dependent Variables	Equality of Variances	Sum of squares	df	Mean square	F	Sig.
Dependent variable 1: Composite score of responses to items on conceptualization	Between groups	287.997	2	143.998	27.608	0.000
	Within Groups	1616.879	310	5.216		
	Total	1904.875	312			
Dependent variable 2: Composite score of responses to items on application	Between groups	27.004	2	13.502	2.825	0.061
	Within Groups	1476.609	309	4.779		
	Total	1503.612	311			
Dependent variable 3: Academic performance of students	Between groups	0.181	2	0.091	0.145	0.865
	Within Groups	142.349	227	0.627		
	Total	142.531	229			

The output of the ANOVA analysis of the comparison between the mean of composite scores of responses to items on conceptualization and application of ideas, and academic performance of selected students with low, medium and high ability to identify a real-life problem is presented in Table 8. It is worth noting from Table 9 that sig. for the independent variable 1 is .000 < 0.05 while sig: = .061 > 0.05 and sig: = .865 > 0.05 for the independent variables 2 and 3 respectively. As there is a statistically significant difference in the means of the composite scores of responses to questions on the conceptualization of abilities of undergraduate students with low, medium, and high capacity to recognize a real-life problem, it is valid to draw that conclusion. The academic performance of undergraduate students with low, medium, and high capacity to recognize a real-life problem does not differ statistically significantly from that of students with low, medium, and high ability to apply concepts. Table 10 displays the findings of the homogeneity of variances test for the data utilized in this instance. From this table, it is discovered that sig: > 0.05 for the independent variables considered, hence it is valid to conclude that there is no statistically significant difference in the variances of responses in the three groups to items on conceptualization and application of ideas, and academic performance. The Post-Hoc multiple comparisons in Table 11 is obtained using Tukey HSD results. From this table, it is deduced that:

Table 10: An overview of the descriptive statistics, ANOVA findings, and multiple comparisons on the correlation between academic success and the capacity to recognize a real-world problem and the overall scores on the conceptualization and application skills items

Test of homogeneity of variances

	Levene statistic	df1	df2	Sig.
Dependent variable 1: Composite score of responses to items on conceptualization	0.753	2	310	0.472
Dependent variable 2: Composite score of responses to items on application	1.223	2	309	0.296
Dependent variable 3: Academic performance of students	0.423	2	227	0.655

1. the mean of composite score of responses to items on conceptualization skills of the selected students with low ability to identify a real-life problem (8.38±0.703; p = .032) is found to be statistically significantly lowest when compared to that of undergraduate students with medium (10.04 ± 0.177; p = .032) and high (112 ± 0.188; p = .000) ability to identify a real-life problem.
2. the mean of composite score of responses to items on conceptualization skills of the selected students with medium ability to identify a real-life problem (10.04 ± 0.177; p = .032) is found to be statistically significantly higher when compared to that of undergraduate students with low ability (8.38±0.703; p = .032) but statistically significantly lower when compared with those with high ability (11.81±0.188; p = .000).
3. the mean of composite score of responses to items on conceptualization skills of the selected students with high ability to identify a real-life problem (11.81 ± 0.188; p = .000) is statistically significantly highest when compared to that of undergraduate students with low (8.38±0.703; p = .000) and medium (10.04 ± 0.177; p = .000).

Also, the nonparametric Kruskal-Wallis H test (one-way ANOVA on ranks) was used to further explore the data. As show in Table 12, there exist no statistically significant difference in the conceptualization of ideas between the different levels of collaborative learning by the students, $\chi^2(2) = 0.984$, p = 0.611, with a mean rank pain score of 149.82 for low, 154.75 for medium and 163.32 for high.

Table 11 Summary of the descriptive statistics, results of ANOVA and multiple comparisons on the relationship between ability to identify a real life problem and composite scores of responses to items on conceptualization and application skills, and academic performance.

- there exist no statistically significant difference in the application of acquired ideas between the different levels of collaborative learning by the students, $\chi^2(2) = 5.376$, p = 0.068, with a mean rank pain score of 161.53 for low, 167.86 for medium and 142.89 for high.
- there was a statistically significant difference in the academic performance (CGPA) between the different levels of collaborative learning by the students, $\chi^2(2) = 12.071$, p = 0.002, with a mean rank pain score of 122.50 for low, 130.54 for medium and 98.15 for high.

Table 11: Summary of the descriptive statistics, results of ANOVA and multiple comparisons on the relationship between ability to identify a real life problem and composite scores of responses to items on conceptualization and application skills, and academic performance

Multiple comparisons								
Dependent variable				**Mean diff. dependent variable (I-J)**	**Std. error**	**Sig.**	**95% confidence interval**	
							Lower bound	**Upper bound**
Dependent variable 1: Composite score of responses to items on conceptualization	Tukey HSD	Low	Medium	-1.653*	0.655	0.032	-3.20	-0.11
			High	-3.428*	0.669	0.000	-5.00	-1.85
		Medium	Low	1.653*	0.655	0.032	0.11	3.20
			High	-1.775*	0.273	0.000	-2.42	-1.13
		High	Low	3.428*	0.669	0.000	1.85	5.00
			Medium	1.775*	0.273	0.000	1.13	2.42
Dependent variable 2: Composite score of responses to items on application	Tukey HSD	Low	Medium	-0.907	0.627	0.319	-2.38	0.57
			High	-1.334	0.641	0.095	-2.84	0.17
		Medium	Low	0.907	0.627	0.319	-0.57	2.38
			High	-0.428	0.261	0.231	-1.04	0.19
		High	Low	1.334	0.641	0.095	-0.17	2.84
			Medium	0.428	0.261	0.231	-0.19	1.04
Dependent variable 3: Academic performance of students	Tukey HSD	Low	Medium	0.09007	0.24803	0.930	-0.4951	0.6752
			High	0.03990	0.25465	0.986	-0.5608	0.6408
		Medium	Low	-0.09007	0.24803	0.930	-0.6752	0.4951
			High	-0.05008	0.11113	0.894	-0.3123	0.2121
		High	Low	-0.03999	0.25465	0.986	-0.6408	0.5608
			Medium	0.05008	0.11113	0.894	-0.2121	0.3123

*The mean difference is significant at the 0.05 level.

Discussion of Results

The difference in the conceptualization of ideas between males and females that is observed in this study though it is not significant statistically can be traced to communication skills which are distinct uniquely between males and females. Wood (Wood, 1994) had once remarked that communication by boys is often characterized by assertiveness to establish status and power, gain respect, and win competitions while communication by females frequently characterized by sharing of feelings and providing support. Moreover, winning a competition requires consistent strategy and extrapolation of ideas which may account for the reason why male students conceptualize ideas better than females. To complement this fact, Dow and Wood (Dow *et al*., 2006) have once remarked that critical thinking skills are perceived differently between males and females due to the fact that female uses critical thinking and problem solve skills more than male though it is been used in a less confrontational and direct approach. The outcome of this study corroborates with the result of Leach (Leach, 2011) which says that the main effect of gender was statistically significant with the mean for males (M = 10.26) significantly higher than the mean for females (M= 9.73). Additionally, the results of this study, which show that male students outperform female students and that gender difference is not a determining factor when it comes to self-efficacy, active learning strategies, and academic performance of undergraduate students, contradict the findings of Animasaun and Abegunrin (Animasaun *et al*., 2016) in a study that included 290 randomly chosen students from the Department of

Mathematical Sciences. However, the justification for the fact that male students have higher ability to apply acquired knowledge might be their nature or prowess bestowed on male more than the female. In terms of the application of acquired ideas, analysis of this study confirms that male undergraduate outstands female undergraduates. This could also be traced to the fact that more male respondents are experts in conceptualizing ideas. Conceptualizing is the process of developing a workable application for a concept. To conceive an idea, one has to create a realistic mental image of how the idea may be realized. It is possible to apply these ideas once conceived, except laziness sets in.

Table 12: Ranks and Test Statistics output of Kruskal-Wallis Test

Ranks			
	How much do you like collaborative learning (reading with friends)?	**N**	**Mean Rank**
Composite score of response to items on conceptualizing	Low	44	149.82
	Medium	144	154.75
	High	126	163.32
	Total	314	
Composite score of responses to items on applying	Low	44	161.53
	Medium	144	167.86
	High	125	142.89
	Total	313	
Acadeemic performance of students	Low	31	122.5
	Medium	104	130.54
	High	96	98.15
	Total	231	

Test Statistics[a,b]			
	Composite score of response to items on conceptualizing	**Composite score of responses to items on applying**	**Acadeemic performance of students**
Chi-Square	0.984	5.376	12.071
df	2	2	2
Asymp. Sig	0.611	0.068	0.002

a. Kruskal Wallis Test

b. Group variable: How much do you like collaborative learning (reading with friends)?

This is apparent in some jobs that require both mental and physical activities. Thus, gender difference can determine the extent to which knowledge is applied. In the report of Glaister (Glaister, 2017) on an overview of Mathematics and further-mathematics at AS and A levels, it is remarked that further-mathematics was designed for students with an enthusiasm for mathematics. In another report, Chukwuyenum (Chukwuyenum, 2013) concluded that critical thinking skills can enhance the understanding of mathematical concepts and vice-versa. Owing to the fact that many subjects are built on the foundation of mathematics, outstanding academic performance (CGPA) of students who offered further-mathematics in secondary school in the university can be traced to the fact that they have equipped themselves with all the intricate values of studying mathematics. In addition, students in this category (i.e. high likeness for mathematics) might have developed high self-efficacy and active learning strategies which are needed to study independently and excel academically (Animasaun *et al.*, 2016) The results of this study also complement the early report in Ref. (Animasaun *et al.*, 2016) , in which it was concluded that there exists a significant difference in the academic performance of students with low and high likeness for mathematics (sig. 0.008) and high and medium likeness for mathematics (sig. 0.000). This is true because students with low interest in mathematics may not have offered further-mathematics in secondary school. Alternatively, they could have been coerced into participating by their parents or instructors. In the same research, it was determined that there is a substantial difference in the academic performance mean of chosen students who offered and did not offer further mathematics in a secondary school and a significant difference in the self-efficacy between the two groups of students. These facts also justify the reason why they possess better ability to conceptualize an idea and apply acquired ideas better. Based on these results, it can be deduced that offering of further-mathematics has a significant impact on the academic performance of undergraduate students. It is worth remarking that students can actually find the study of further-mathematics to be attractive if their negative perception towards mathematics can be changed. Moreover, it is possible to focus on the relevance of the subject as it prepares students for the compulsory mathematics courses in the university. However, students who offer further-mathematics have better academic performance especially in mathematics related courses than their fellow students who do not offer further-mathematics as they have better knowledge and understanding of mathematical concepts and ideas than their counterparts that do not offer further-mathematics.

It is worth noticing that students with prior knowledge of further-mathematics in secondary school conceptualize and apply ideas more than their counterparts who did not offer further-mathematics in secondary school, although the difference between the means is not statistically significant. This is justified as the mean of composite scores of responses to items on conceptualization and application of ideas are in favor of those undergraduate students with prior knowledge of further-mathematics in secondary school. In this study, offering of further-mathematics in secondary school is found to contribute immensely to the academic performance of undergraduate students, as those who provide ”Yes” to the question ”Did you offer further-mathematics in secondary school ?” have higher mean score than the other group. It has been emphasized by Animasaun and Abegunrin (Animasaun *et al.*, 2016) that Mathematics is a powerful tool in developing thinking and reasoning skills, and in fact, academic performance depends largely on the extent to which one can think and reason about a problem to give an appropriate solution. In this study, the academic performance of undergraduate students is found to be significantly different among the students with low, medium and high likeness for collaborative learning. This supports the belief that collaborating with others by discussing results, findings and ideas have an impact on the academic performance of students. What can take several hours to comprehend might not take few minutes to capture when one engages in collaborative learning. Scardamalia and Bereiter (Scardamalia *et al.*, 1996) and Vygotsky (Vygotsy, 1978) stressed the fact that there exist intellectual benefits when students collaborate with peers to discuss ideas together. In addition, Vygotsky (Vygotsy, 1978) maintained that the use of dialogue and social interaction in group-based learning can be viewed as a form of scaffolding, and theoretically speaking, students help each other carry out a task beyond their individual capabilities. However, the result of this current finding shows that participating in collaborative learning on an average scale enhances academic performance more than participating on a low or high scale. This is justified as the composite (on academic performance) of students with medium likeness for collaborative learning is observed to be highest when compared to those of other two groups. This result supports the belief that engaging in too much collaborative learning will amount to waste of time and will not allow students to have time for personal rumination and reasoning. Although the statistical analysis of Table 4 shows that there is no statistically significant difference between the means of composite scores of responses to items on conceptualization and application of ideas, it is worth noticing that undergraduate students with high likeness for collaborative learning have the highest composite score. This implies that students with high likeness for collaborative learning conceptualize ideas best when compared to other two groups. It has been stressed by Scardamalia and Bereiter (Scardamalia *et al*., 1996) that collaborative learning facilitates and contributes to the development of student critical thinking. In addition, Vygotsky (Vygotsy, 1978) discovered that peer interaction during collaborative learning or small-group learning can be beneficial for the development of critical thinking. It is also worth noticing that participating in collaborative learning on a medium scale contributes immensely to the extent to which ideas are applied.

Conclusion and Recommendation

In this study, a new instrument for measuring the first two cognitive components of critical thinking is presented and used successfully. Psychometric properties of the data extracted from the instrument were examined; it is worth remarking that the questionnaire is valid and reliable. The impacts of gender difference and offering of further-mathematics in secondary school on the conceptualization of ideas, application of ideas and academic performance of undergraduate students in three different Departments (Mathematical Sciences, Statistics and Computer Science) of the Federal University of Technology, Akure, have been examined. Based on the results of this research, it is valid to conclude that

- male students applied acquired ideas/knowledge more than their female counterparts due to the structuring of ideas in order to earn respect whereas there is no significant difference in their ability to conceptualize ideas and academic performance.
- participation in collaborative learning on an average scale enhances the academic performance of undergraduates but does not have a significant effect on application level of their level of critical thinking.
- undergraduate students with a high ability to identify a real-life have the highest ability to conceptualize ideas.
- male and female students possess equal ability to conceptualize ideas, although the average composite scores of male respondents are higher than that of female respondents. Academic performance of males and females is not significantly different, meanwhile, average CPGA of male students is found to be higher than that of females.
- undergraduate students who offered further-mathematics in secondary school outperform those who did not offer, which shows the importance of the subject. Undergraduates who offered further-mathematics in secondary poses higher ability to conceptualize and apply ideas better than those students who did not offer the subject in secondary school.

Based on the outcome of this survey research, the following recommendations are offered:

- Female undergraduates are encouraged to develop the ability to pull ideas together to form a concept and arrange the ideas into a pattern. This would help them the conceptualize ideas better and perform better academically.
- Parents are to note that offering of further-mathematics in secondary school is a factor that can help their children to develop the ability to conceptualize ideas, apply acquired ideas and perform better in the university.
- Undergraduates are advised to be conscious of collaborative learning owing to the fact that they would not be able to develop the ability to apply acquired ideas excellently. Undergraduates who prefer this kind of learning would only possess better conceptualization of idea. Moderate involvement in collaborative learning is hereby suggested.
- The governing council of tertiary institutions, Lecturers, and Parents should bear in mind that the ability to identify a real life problem is a factor that can help students to develop the power to conceptualize ideas; hence it should be instilled.

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Conflict of Interest

The authors do not have any conflict of interest.

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