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Critical Thinking Ability As A Correlate Of Senior Secondary School Students' Achievement In Physics In Sokoto State, Nigeria

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Abstract

This paper examined critical thinking as a correlate of students' achievement in physics in Sokoto State, Nigeria. This study adopted ex post facto research of the co-relational type. The population for the study was Senior Secondary School II (S.S.S. II) students in Sokoto State. The sample consisted of 731 S.S.S. II offering physics proportionately selected from Senior Secondary Schools across the three senatorial districts in Sokoto State, Nigeria. Research instruments employed to elicit data for the study were the Critical Thinking Inventory (SCTI), and Physics Achievement Test (PAT). The instruments were validated by experts in science education and physics giving reliability coefficients 0.86 and 0.76 respectively. The data gathered were analysed using Pearson Product Moment Correlation Coefficients (PPMC) and Fishers-z transformation (Z-test) statistic at .05 level of significance. The findings of the study revealed that: there was a statistically significant relationship between students' critical thinking ability and their achievement in physics ($r = 0.23$, $p < .05$); there was no statistically significant difference in the strength of the relationship between students' critical thinking ability and their achievement in physics in favour of female students; and there was a statistically significant difference in the strength of the relationship between critical thinking ability and physics achievement in favour of public schools. It was recommended that students should be trained on how to think critically to be able to predict correctly their achievement in physics.

***Keywords*:** *Critical Thinking, Correlate, students', Achievement and Physics*

1. Introduction

Science is defined as a multidisciplinary human activity that involves a planned systematic investigation and understanding of the world, nature, and the universe (Olorundare, 2014). Abdullahi (1982) had earlier defined science as activities culminating into a testable, falsifiable, and verifiable body of knowledge. He classified science into conceptual or basic science and applied or technical science. Basic science has a dual nature; it is a body of knowledge and a process of acquiring and refining knowledge. Examples of subjects under basic science are Biology, Chemistry and Physics. Technology, on the other hand, is primarily concerned with finding solutions to practical problems that confront the man. Examples are Engineering, Medicine, and so on. Observation of the above meaning of science suggests the inquiry nature of science (Physics in particular) as it emphasises the practical nature of science since the subject cannot be meaningfully understood without the students' active participation which necessitates practical activities.

Physics is a major branch of science, concerned with the laws that govern the structure of the universe, the forms of matter, energy, and their interactions (Bello & Akinfesola, 2015). Physics is a branch of

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science that is concerned with energy, and their interaction (Omosewo, 2009); and it is the most basic of the sciences because its concepts, and techniques corroborate the progress of all branches of science (Ekee, 2010). Physics is a cross-cutting discipline that has been implemented in many sectors of economic advancement which includes health, agriculture, water, energy, and information technology. In medicine, X-rays, radioisotope, and resonance imaging, are used. In addition, the design of machines and electronics all depend on advances made from physics in technology (Mankilik & Ofodile, 2015).

Physics being a branch of science is crucial for effective living in the modern age of science and technology. Given its applications in industry and many other places in society, it is necessary that every student must be allowed to acquire its concepts, principles, and skills (NERDC, 2009). Despite the importance of Physics to the scientific and technological development of our nation, students' performance and understanding of the subject have fluctuated over the years. This is evidenced by the low enrolment of students in physics. Researchers such as Badmus (2020) and Bello and Akinfesola (2015) believed that students' performance in the subject was poor.

Improving the learning of Physics and achievement in it requires a lot of input from the teachers because the role of the teacher in the classroom is important. The teaching approach that a teacher adopts and the available instructional materials may affect students' achievement (Ukoh, 2013). Therefore, it can be deduced that the use of appropriate teaching strategies with relevant illustrations is critical to successful teaching and learning of Physics. Illustrations in the physics classroom come inform of graphical representation/display or a more complex diagrammatical presentation of an idea. The cognitive aspects of development that students' requires in understanding and interpreting these display involves thinking activities in the brain.

Critical thinking is a form of thinking based on purposeful and autonomous decision-making as a result of interpretation, analysis, evaluation, and sense-making (Facione, 2020). Critical thinking skills are very popular cognitive skills in science education in recent years. Because understanding knowledge and creating a relationship by analyzing this knowledge and producing new and different knowledge from the existing knowledge; that is, synthesis skills are related to critical thinking (Lenn, Hong, Kwan, & Ying, 2014).

The body of knowledge available in the area of critical thinking provided evidence of it contributing to students' achievement. Acharya (2018) explored critical thinking for secondary level students in chemistry: From insight to practice. The study examined hands-on activities based on improvisation of low cost and no cost materials that have direct and indirect impacts on critical thinking practices in secondary science classrooms in Nepal. It also explored the science teachers' activities for the development of critical thinking practices in chemistry for the secondary school students. The study had highlighted the major conceptual and methodological issues in identifying, assessing and exploring critical thinking as well as the implication of chemistry education for the exploration of children's creative and critical thinking. Based on the qualitative research approach, the study used classroom observation and an interview with the students as the tools to pursue the research objectives. It was observed that there was a great role of hands-on activities to foster the critical thinking in chemistry in an informal class setting.

Li, et al (2021) investigated Critical thinking, emotional intelligence, and conflict management styles of medical students: A

cross-sectional study. The aim of the research was to evaluate critical thinking among medical students, and the correlations of emotional intelligence and five conflict management styles with critical thinking. A cross-sectional study of medical students from the Jilin University was conducted using a questionnaire. Data were analysed using t-tests, one-way ANOVA, Pearson correlation analysis, and linear regression analysis. 269 medical undergraduates completed this study. The mean critical thinking score was 281.12 ± 27.40, with139 participants (51.67 %) indicating positive to strong critical thinking tendency. Gender or year of study was not statistically significant associated with critical thinking. Emotional intelligence was a significant predictor of critical thinking: higher emotional intelligence scores were associated with higher critical thinking scores. Integration, domination, and compliance showed a significant association with critical thinking. Further investigation to explore these associations and the role of inclusion of these topics in the undergraduate curriculum was recommended.

Ren, Tong, Peng & Wang (2020) in their study on critical thinking predicts academic performance beyond general cognitive ability: Evidence from adults and children. Both critical thinking (CT) skills and dispositions were investigated in order to obtain a complete picture of CT and its relations to academic performance and general cognitive ability including fluid intelligence, working memory and processing speed. Measures of these variables were administrated to both university young adults (N = 232, study 1, a self-report scale was used for assessing academic performance) and primary school children (N = 158, study 2). Both studies showed that CT indicated by skills and dispositions made unique contributions to academic performance even when general cognitive ability was controlled for. Further, it was mainly CT dispositions that uniquely contributed to academic performance while the contribution of CT skills to academic performance largely overlapped with general cognitive ability. The researcher's findings provide a first step toward understanding CT as a distinct construct from general cognitive ability in relation to learning and academic performance.

Musa, (2020) investigated the Relationship between Critical Thinking Levels and Academic Achievement Levels of Students in Faculty of Sports Science. The research population consists of 1170 students studying at the Usak University, Faculty of Sport Sciences in the fall semester of 2019/2020. The sample group consisted of 334 students selected from the university by random sampling method through voluntary participation. California Critical Thinking Disposition Inventory (CCTDI-R) which was originally developed by Facione et al. and whose Turkish validity reliability study was conducted by Kokdemir was shortened. The Turkish version of it (CCTDI-R) was used. The academic achievement levels of the students were obtained through Usak University Student Information System (SIS). Frequency, percentage, and arithmetic average were used to evaluate academic performance of the students and the data obtained with critical thinking tendency scale. Correlation analysis was used to determine the relationship between variables and regression analysis was used to determine the effect of independent variable on dependent variable. The results revealed that there was a positive relationship between students' critical thinking levels and their academic achievement levels. A positive correlation was observed between students' academic achievements and their tendency to be careful about potentially problematic situations in their critical thinking skills sub-

dimensions and to use objective evidence even in the face of difficult problems.

Affandy, Aminah, and Supriyanto (2019) investigated the correlation of character education with critical thinking skills as an important attribute to success in the 21st century. The test instrument used was a critical thinking skill test using 4 items from the national exam, a character education questionnaire and Focus Group Discussion (FGD). The sample used was 99 students from all students in SMA Batik 2 Surakarta. The data obtained were analyzed using Bivariate Pearson to determine the content validity and Cronbach alpha to find out the reliability of the instrument. The test used to determine the relationship of character education with critical thinking skills using the Mann-Whitney U test. The analyzed result instrument reliability is good enough with Alpha value 0.79. Test results show that there was a relationship between character education and critical thinking skills.

It has been established by several researchers that critical thinking predicts students' achievement (Ren, Tong, Peng & Wang 2020; & Musa, 2020). In contrast, Li, et al (2021), found no significant relationships between critical thinking skills and students' achievement. Thus findings on the influence of critical thinking on students' achievement appear inconclusive, thus the need for further study in this area. In addition, it was observed that many of the studies were focused mostly on subjects like psychology, social studies, and primary science. Based on these facts, the present study is out to investigate critical thinking as a correlate of senior school students' achievement in physics in Sokoto State, Nigeria.

Nnamani and Oyibe (2016) investigated gender and academic achievement of secondary school students in social studies in Abakaliki urban of Ebonyi State. The study focused on gender and academic achievement of secondary school students in Social Studies. The population of this study comprised of three thousand four hundred seventy-nine (3,479) Junior Secondary School II (JSS II) students selected from all the secondary schools in Abakaliki urban of Ebonyi State. The instrument used for data collection was Social Studies Achievement Test (SOSAT). Data were analyzed using mean and standard deviation for all research questions, and analysis of co-variance (ANCOVA) was used to test the null hypotheses at .05 level of significance. The findings of the study revealed that the mean achievement score of female secondary school students was higher than the mean achievement scores of male students. It was also reviewed that there are significant different in the mean achievement of secondary school students in Social Studies based on gender. It was recommended that Social Studies teachers should re-assess their classroom instructional practice because there is a need for them to shift from instructional practice that will give the students equal opportunities to excel in instructional activities.

Priulla, D'Angelo, & Attanasio, (2021) analyzed Italian university students' performance through segmented regression models: gender differences in STEM courses. The author investigated gender differences in university performances in Science, Technology, Engineering, and Mathematics (STEM) courses in Italy, proposing a novel application through the segmented regression models. The analysis concerns freshmen students enrolled at a 3-year STEM degree in Italian universities in the last decade, with a focus on the relationship between the number of university credits earned during the first year (a good predictor of the regularity of the career) and the probability of getting the bachelor degree within 4 years. Data was

provided by the Italian Ministry of University and Research (MIUR). The analysis of the collected data confirms that first-year performance is strongly correlated to obtaining a degree within 4 years. Furthermore, it was showed that gender differences vary among STEM courses, in accordance with the care-oriented and technical-oriented dichotomy. Males outperform females in mathematics, physics, chemistry and computer science, while females are slightly better than males in biology. In engineering, female performance seems to follow the male stream.

Badmus (2020) studied senior school students' metacognition, spatial visualisation, mathematical ability and attitude as predictors of physics achievement in Kwara State. An ex post facto research of the co-relational type was adopted for the study. The population of study was S.S.S. III students in Kwara State. The sample consisted of 857 students from intact classes selected from 21 co-educational senior secondary schools across the three senatorial districts in Kwara State. Three research instruments were employed in data collections which are Students' Metacognition Inventory (SMI), Students' Spatial Visualisation Test (SSVT) and Students' Attitude toward Physics Inventory (ATPI). Mean score, One-way MANOVA, PPMC and multiple regression statistical tools were employed for data analysis at .05 level of significance. The findings of the study revealed that students' spatial visualisation ability significantly predicted their achievement in physics. Gender and school type as moderating variables significantly influence the prediction between students' spatial visualisation ability and their achievement in physics. It was recommended that students' gender and school type should be considered by physics teachers as it helps to improve their achievement in physics.

Findings on the influence of gender and school type on students' achievement appear inconclusive as some researchers found it to influence students' achievement while others find it to have no significant influence on students' achievement. This is why gender and school type was chosen as part of the variables of interest in this study.

Students' poor understanding and inability to solve a given physics problem appropriately have called for concern among physics educators and other stakeholders over the years. Investigations into the circumstances that are responsible for this under-achievement of students in physics revealed among others, poor motivation, negative attitude towards the subject, inadequate learning resources, students' critical thinking abilities, and poor students' interest towards the subject amongst others (Ukoh, 2013). Despite the large number of studies on students' difficulties in physics problem solving and students' achievement in physics (Badmus, 2020; Bello & Akinfesola, 2015), very few attempts have been made to relate students' susceptibility to the errors in physics problem solving to their reasoning level.

Researchers have attributed students' achievement in science to critical thinking (Ren, Tong, Peng & Wang 2020; & Musa, 2020). In contrast, Li et al (2021) revealed that there was no statistically significant difference between students' academic achievement and critical thinking disposition. Thus findings on the influence of critical thinking and students' achievement in physics appear inconclusive, therefore the need for more empirical research on the relationship between students' critical thinking ability and their achievement in physics. It is, therefore, against this background, that this study seeks to investigate critical thinking as a correlate of senior secondary school students' achievement in physics in Sokoto State, Nigeria.

2. Method

This research adopted ex post facto research of co-relational type. The justification for adopting ex post facto research was that, the researcher had no direct control on independent variables, testing of the relationship between independent and dependent variables were observed. In this study, students' critical thinking was independent variable while students' achievement in physics was a dependent variable. Students' gender and school type were moderating variables.

The population covered by this study were all senior secondary school students' (45,991) offering physics in Sokoto State, Nigeria. The target population for the study were all the senior secondary school students' two (SSS II) offering physics in both public and private schools. The sample for this study were seven hundred and thirty-one (731) senior school students (SSS II) offering physics proportionately selected from senior secondary schools across the three senatorial districts in Sokoto State, Nigeria. Table 1 presents the school distribution across the three senatorial districts.

Table 1. School Type Distribution in Sokoto State

Senatorial Districts	**School Type**					**Total**
	Public Schools				Private Schools	2
	Total	Mixed Schools	Male only	Female only	-	-
Sokoto North	43	2	20	21	15	58
Sokoto Central	55	3	27	25	33	88
Sokoto South	33	2	16	15	28	61
Total	**131**	**7**	**63**	**61**	**76**	**207**

Purposive sampling technique were used in selecting the participating schools across the three districts following the students' population in each of the selected schools based on school type (public schools or private schools). This study involved SSS II students' because they have been taught greater part of the SSCE physics syllabus and are matured enough for the variables considered in this study unlike SSS I that are new in the system and SSS III that are preparing for external examination.

Two instruments were employed in this study namely: Students' Critical Thinking Inventory (SCTI) and Physics Achievement Test (PAT). Students' Critical Thinking Inventory (SCTI) was adapted from Facione (2017) "Critical Thinking Inventory". This instrument was initially developed in California to measure the critical thinking ability of senior school students. It consisted of twenty (20) corresponding statements with options of "YES or NO". The responses to odd number statements were "YES" while responses to even number statement were "NO". For every correct response a respondent score 5points while for each wrong response, a respondent scores zero (0). A respondent that score 50% upward are considered as having high critical thinking ability while a respondent that score below 50% downward are considered as having low critical thinking ability.

The second instrument, Physics Achievement Test (PAT) was a researcher designed test with items structured to test students' knowledge, comprehension, and application, based on Bloom's taxonomy of educational objectives. These test consisted of 25 structured multiple choice questions on Physics topics. The contents of the test were drawn in line with performance objectives stated in the SSS Physics curriculum after the researcher conducted a visibility study to ascertain the level of coverage of the curriculum. The responses retrieved from the sample schools help the researcher in developing the PAT.

Each question has a maximum score of one (1) mark.

It is of note that, students' name did not appear on any of the test pages nor answer booklets. Students' participation was voluntary and their freedom to pull out of the research process at any stage was accommodated.

The face and content validity of the instruments were established by given the instruments to three (3) experts in science education, from the department of Science Education, University of Ilorin, Nigeria; two (2) psychometric experts from the department Guidance and Counselling, University of Ilorin, Nigeria and two (2) practicing physics teachers in senior secondary schools in Sokoto to check and make necessary adjustment if the instruments falls within the subjects (respondents) area of coverage and also check if it align with the objectives of this study.

Consequently, the item analysis of PAT was conducted, where the difficulty and discrimination indices were calculated for items in the multiple choices. This was to ensure that these items were not too difficult nor too easy; and spread across different knowledge levels of the students. The initial drafts of 30 items were administered to SSII students in a non-participating school in Sokoto. However, 5 items were discarded because the difficulty indices were below 0.5 and thus, the final draft comprised 25 multiple choice items.

Also, in order to ascertain the reliability of SCTI, the instrument was trial tested. A split-half reliability method was employed involving 30 non-participating SSSII students in Sokoto. The resulting data from SCTI was analysed using Cronbach's alpha. The reliability coefficient of SCTI was .86. Hence, the instrument was adjudged to be reliable.

The researcher obtained a letter of introduction from the Head of Department of Science Education, University of Ilorin to the Principals of the selected senior secondary schools. The researcher personally visited the schools where the study were conducted to seek for the principals permission and the consent of the physics teachers of the selected schools were sought by administration of consent form. The participants (students' and their parents) were given a copy of the consent form so as to get their willingness to participate in the study or otherwise. This was done with the help of physics teachers in the selected schools. The researcher employed the service of the physics teachers in the selected schools to enhance the administration of the research instruments. Students Critical Thinking inventory (SCTI) was the first instrument that was administered to the students and lasted for 30minutes after which the Physics Achievement Test was administered which lasted for 40minutes. The administered instruments were retrieved from the respondents for scoring and analysis.

Students' participation was voluntary and they were not exposed to any unfavourable conditions and treats, while the identity of the selected schools and participants were not disclosed at any point in this study. All gathered data were handled with utmost confidentiality and used exclusively for the purpose of this study. To avoid plagiarism, the researcher ensured that all citations were properly referenced and paraphrased.

The data collected from the field were subjected to appropriate statistical techniques in order to answer the research questions and test the formulated hypotheses. All the research questions were answered using descriptive statistics of frequencies, simple percentages, and mean. Hypotheses 1 was tested using Pearson Product Moment Correlation Coefficients (PPMC) while hypotheses 2 and 3 were tested using Z-test statistic with the aid of IBM SPSS Statistical package (version 23). Appropriate

recommendations were made and relevant conclusion was drawn based on the findings of the study.

3. Result and Discussion

The results obtained from the statistical analysis of data are presented as follows. Corresponding research questions and hypotheses were analysed and results presented as follows.

The data on Table 3 represents the demography of respondents based on gender and school type. Table 3 revealed that out of the 731 students that completely participated in the study, 449 students representing (61.4%) were male students, while 282 students representing (38.6%) were female students. The implication is that more male students participated in this study. Table 5 further revealed that 478(65.4%) students were from public secondary schools while 253(38.0%) students were from private schools. this indicated that greater percentage of respondents were from public secondary schools.

The result of Pearson-product moment correlation (PPMC) shows that there was a positive correlation ($r = .23$, $p < .05$, $df = 729$) between students' critical thinking ability and students' achievement in physics with p-value less than .05 (.00), indicating significance, thus, hypothesis 1 is rejected. It implies that the relationship between students' critical thinking ability and students' achievement in physics is weak, thus, having positive impact on their achievement is largely minimal.

After having subjected students' gender to Z-test to determine if truly there was a significance difference in the relationship between critical thinking ability and students' achievement in physics, the result shows that there was no statistically significant difference in the strength of correlation between critical thinking ability and students' achievement in physics in favour of female with higher correlation ($r = .27$) compared with that of male with correlation ($r = .18$) as the Zobs (-1.25) is in-between -1.96 and +1.96 boundary. Hence hypothesis 2 is not rejected which implies that, there was no significant relationship between students critical thinking ability and their achievement in physics based on gender. Despite the relationship that existed between critical thinking ability and students' achievement in physics as observed in hypothesis 1 results, female students did not perform better than their male counterparts.

After having subjected students' school type to *Z*-test to determine if truly there was a significance difference in the relationship between critical thinking ability and students' achievement in physics, the result shows that there was a statistically significant difference in the strength of correlation between critical thinking ability and physics achievement in favour of public schools with higher correlation ($r = .26$) compared with that of private schools with correlation ($r = .22$) as the Z_{obs} (3.09) is outside -1.96 and +1.96 boundary, thus hypothesis 3 was rejected. This implies that, despite the relationship that existed between critical thinking ability and students' achievement in physics, as observed in hypothesis 1 results, public school students did perform better than their private school counterparts.

This study found significant correlation between students' critical thinking ability and their achievement in physics. Thus, hypothesis 1 was rejected. It implies that the relationship between students' critical thinking ability and achievement in physics is weak, thus, having positive impact on their achievement is largely minimal. This prediction may be as a result of the instrument employed which can be adduced to an aspect of intelligence testing. The research of Ren, Tong, Peng & Wang (2020), and Musa, (2020) affirmed the position

of this study that critical thinking ability correlates students' achievement in physics. In contrast with Li et al (2021) reported no significant relationships between critical thinking skills and students' achievement.

Analysis of the influence of gender on the relationship between students' critical thinking ability and their achievement in physics shows that there was no statistically significant difference in the strength of correlation between critical thinking ability and students' achievement in physics based on gender. Hence hypothesis 2 was not rejected which implies that, despite the relationship that existed between critical thinking ability and achievement in physics as observed in hypothesis 1 result, female students did not perform better than their male counterparts. The position of this study is in line with Li et al (2021) who revealed that there was no significant effect of gender on students' achievement in Physics although, females did better than males. This contradicts the findings of Badmus (2020) and Priulla, D'angel & Attansio (2021).

Analysis of the influence of school type on the relationship between critical thinking ability and students' achievement in physics shows that there was statistically significant difference in the strength of correlation between critical thinking ability and students' achievement in physics in favour of public schools with higher correlation. Thus hypothesis 3 was rejected. This implies that, despite the relationship that existed between critical thinking ability and students' achievement in physics as observed in hypothesis 1 result, public school students still perform better than their private school counterparts. This study shared the same position as Badmus (2020) who reported a significant difference between public and private senior secondary school students' achievement in the physics.

4. Conclusion

Based on the findings of this study, it was concluded that senior secondary school physics students exhibit different level of critical thinking which could improve or mar their learning outcome, particularly, in physics. Therefore, this study concludes that, students' critical thinking ability can positively predict their academic achievement in senior secondary school physics.

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