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Critical Thinking Skills of Physics Teachers for Inquiry Based Learning Practices

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Abstract--- *This study aimed at investigating the critical thinking skills of physics teachers in inquiry-based classroom. Development of critical thinking became inherent in education because it is a tool for attaining intellectual discipline, integrity, freedom, citizenship, creativity and empathy of every society. Descriptive analysis was used on the Lawson classroom reasoning test administered to a sample of 90 IBL physics teachers in Kebbi state secondary schools, the overall mean score value was calculated to be = 26.83 out of 120 obtainable score. The result indicated a weak level of critical thinking skills of the teachers. Further analysis shows that the teachers are weak in hypo-deductive reasoning, deductive reasoning control and combinational reasoning skills. Teachers with low critical thinking may find inquiry based classroom monotonous. Therefore, to improve the practice of IBL among the physics teachers, their critical thinking skill needs to be strengthened especially in making hypo-deductive reasoning, deductive reasoning control and combinational reasoning skills.*

Keywords--- *Critical Thinking Skills Inquiry-Based Learning and Physics Teachers.*

I. INTRODUCTION

There is a paradigm shift from the old traditional chalkboard method of teaching to a more active learning all over the world. One form of active learning is the inquiry based learning which is defined by the [1] which states that: Inquiry is a multi-faceted activity that involves making observations, posing questions, examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyse, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking and consideration of alternative explanations (p. 23). The method has been proven to be a source of solving tomorrow's problem in today's classroom, it helps to deepen the understanding of individual rather than memorization of facts.

The Nigerian government spent a lot in training the physics teachers on new methods of teaching like the inquiry-based learning but yet the teachers does not complement by practicing the strategy in teaching and learning of physics which lead to students failing physics in their external examinations invariably resulted to a meagre number of them gaining admission in science engineering and technology of our tertiary institutions [2-5]. Parents and stakeholders in education are accusing the teachers for the failure of their wards. Teachers on the other hand refused to admit the allegations [4-5]. This predicament is worth investigating conscientiously the critical thinking skills of the physics teachers

Similarly, critical thinking skills among teachers become imperative to foster the 21st century learning skills. This thinking is seen by scholars as having a diverse views of the definition of critical thinking advanced by

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literature for instance, [7] opined that thinking is the main activity in a human being, a different part that makes a human distinct from other creatures. Suffice it to say; it is a way to move toward self-actualization in every human being. There are diverse views of the definition of critical thinking advanced by literature for instance Bloom [8] defined critical thinking (CT) as the mastery of a set of skills such as knowledge, comprehension application, analysis, synthesis, evaluation, and applying the best when faced with a novel situation. Critical thinking is aimed at enhancing curiosity and creativity; it is a life skill not just learning, it enhances problem solving ability and many others. There are diverse views advanced by research on teaching CT some opined that CT can be taught while others stayed at the contrary. Those in favour argued that CT can be taught through constantly asking questions that stir up analyses, interpretations, evaluations, explanations, and inferences and following up by demanding thoughtful and fair-minded explanation of the reasons for those judgments [9-11]

Researchers like [8,11-14] have acknowledged the need to shift from knowledge-based instruction to a novel approach in which the focus is to foster thinking ability. This stressed the necessity for including critical thinking in education. The focal point for this revolution should start with the teacher education because of the wide belief among educationists that teacher education is the foundation of any educational system and is one of the major signs of quality education [15]. Achor [16,17] pointed that the 21stcentury teachers are to promote quality education. They argued that quality education results in higher order thinking capabilities.

1.1 Inquiry-Based Learning

IBL instruction is based upon constructivist views of learning, where students develop their ideas and concept, follow the action rather than precedes it. The activity leads to the concepts; the concepts do not lead to the activity [18]. Since IBL teaching is based on constructivism, Students are encouraged to use their prior knowledge and experiences, answer questions formulated by them or posed to them for learning to occur. Furthermore, [19] described IBL as the use of questions and problems as a catalyst for learning, which often includes student-centred activities, to engage students and encourage them to become active participants in their own learning process. On teachers who use IBL methodologies present students with opportunities to actively engage in the lifelong learning by making observations, gathering data, drawing conclusions, and practice the knowledge gained [19]. Also [20] posit that teachers' understandings of inquiry are vital considering the social context in the classroom.

To further buttress the point on the realities of IBL meta-analysis of research on IBL teaching demonstrated that this is a useful teaching method [18]. However, teachers may not understand precisely what scientific inquiry is and what changes in instruction and organization of the curriculum are necessary to implement it [18,21-23]. In another study by [24] observed that few highly-motivated teachers could describe what IBL instruction was; most equated it with hands-on learning. IBL has been proven to have a range of inquiry approaches to education which moves away from passive transmission-based pedagogy such approaches includes project-based learning [25-27] problem-based learning [28,29] challenge-based learning [30-32], authentic intellectual work [33], discipline-based inquiry and design-based learning [34]. On the effectiveness of IBL [35]. [36] viewed that materials taught through inquiry-based learning increases critical thinking when compared with traditional teaching methods.

One of the main arguments against inquiry is the idea that it is too time consuming, and it does not allow the coverage of the content. There are also other barriers to using inquiry in the classroom. Lederman [20] conducted a follow up study involving teachers who had taken a science research course. The teachers stated that the course helped them to comprehend how to teach using scientific research; however, they did not do much of it because of absence of time, absence of student background information, and absence of teaching experience. Involvement in an inquiry-based course is only a start, and the obstacles to investigation in the sector need to be removed. If there are no mentors who use inquiry or others with whom they can talk, their capacity to work on enhancing their abilities is restricted. Some teachers lack the content knowledge and pedagogy necessary to teach science as inquiry. Many teachers who went to professional development sessions regarding the use of science inquiry were initially very excited and motivated to teach science as inquiry.

However, [37] revealed that when educators were confronted with restricted budgets; materials management; student security; student evaluations; time constraints; content knowledge constraints; and absence of assistance from the administration and peers, their enthusiasm had waned and modifications had not been integrated into their teaching. [38] confirmed that those who do not have cash and help may not have what is required. IBL teaching has been described to be in three basic forms these are structured, guided and open inquiry.

1.2 Critical Thinking Skills

CT was built on solid frameworks beginning primarily with the works of [8], who identified six levels within the cognitive domain, each of which related to a different level of cognitive ability. Knowledge focused on remembering and reciting information. Comprehension concentrate on connecting and organising previously learned information. Application focused on applying information according to a rule or principle in a specific situation. The analysis was defined as critical thinking focused on parts and their functionality in the whole. The synthesis was identified as critical thinking concentrate on putting pieces together to form a new and original whole. The evaluation was defined as critical thinking focused on valuing and making judgments based on the information. Critical thinking is deemed to take place when students are required to perform in the Analysis, Synthesis, and Evaluation levels of Bloom’s taxonomy. Apart from Blooms’ taxonomy many other taxonomies were developed such as [39] framework for knowledge and skills, [40] taxonomy follows and [41] taxonomy to mention but a few. Besides, a possible weakness of the frameworks above is that they do not adequately elaborate on the way one applies higher-order thinking processes [39,42,43]. The following research review indicates the way teachers view critical thinking skills, how to teach critical thinking.

A study conducted by [44] in Jordan among secondary school social studies teachers revealed that Jordanian secondary school social studies teachers have little familiarity with the definition and teaching strategies of critical thinking. Also [45] complained of lack of thinking skill usage in K-12 classrooms in his write up on what exactly do “fewer, clearer, and higher standards” really look like in the classroom. Mark [46] identified three constraints preventing critical thinking as class subjects: (a) key tensions are involved in teaching critical thinking in an examination culture (b) what constitutes the boundaries of critical thinking (c) who are the professionals of critical thinking. Studies on CT skills were conducted from different countries of the world, however, little or less literature are available on teachers’ critical thinking in Nigeria. This might be due to the curriculum which has been set on the chalk board teacher centred method.

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Research suggested that good critical thinkers make better decisions and judgements in complex situations [47] engage less in cognitive bias and heuristic thinking [13,48] and are more likely to get better grades, become more knowledgeable and more active citizens, and are often more employable than others CT skills are vital in educational settings because they allow individuals to go beyond simply retaining information, to actually gaining a more complex understanding of the information being presented to them [49, 50]. Most challenging issue in the study of CT is the appropriate instrument to measure the critical thinking skill of adults. Of course, there exists a lot of instrument for testing the CT skills of students, for instance, the Watson Glaser (W-GCTA), the California Critical Thinking Test (CCTI) California Critical Thinking Disposition Inventory (CCTDI) and others. Although the development of critical thinking (CT) is a major goal of science education, adequate emphasis has not been given to the measurement of CT skills in specific science domains such as physics This paper is on physics teachers, it will be more appropriate for the physics teachers to be tested in their subject domain, unfortunately, [51] asserts that although an important goal of introductory physics labs is to train students in scientific reasoning and critical thinking, currently there are no standard tests in physics designed to assess such skills that pave way for them to start the process of developing and validating the Physics Lab Inventory of Critical thinking (PLIC), an assessment to probe students' critical thinking abilities in physics lab courses.

Based on the report of Quinne this paper made use of the Lawson’s Test of Scientific Reasoning (LTSR) provides a solid starting point for assessing scientific reasoning skills [52,53]. The test is designed to examine a small set of dimensions including (1) conservation of matter and volume, (2) proportional reasoning, (3) control of variables, (4) probability reasoning, (5) correlation reasoning, and (6) hypothetical-deductive reasoning. These skills are important concrete components of the broadly defined scientific reasoning ability. The test has been tried by a lot of researchers of physics for example [54], on the Force and Concept Inventory (FCI) and Conceptual Survey of Electricity and magnetism (SCEM) Likewise, [55] on the force concept inventory (FCI) in analysing results for a course in introductory mechanics for prospective science teachers. It should be noted that CT skills, as suggested by research, that good critical thinkers make better decisions and judgments in complex situations [47], engage less in cognitive bias and heuristic thinking [13,48] and are more likely to get better grades, become more knowledgeable and more active citizens, and are often more employable than others. Although, [56,57] disputed this argument in their reports on students learning skills assessment in Uganda and Ghana respectively, perhaps due to their inclination to their national curriculum. CT skills are vital in educational settings because they allow individuals to go beyond simply retaining information, to actually gaining a more complex understanding of the information being presented to them [49,50]. CT skills are also important in social and interpersonal contexts where good decision-making and problem-solving are needed on a daily basis [58].

The Kebbi state physics teachers read about inquiry–based learning method as a methodology of teaching just like any other method of teaching, even though, few of the physics teachers were found to have undergone a professional development training on IBL as an active form of learning. But the level of critical thinking of the physics teachers is yet to be determined. That is the goal of this paper, considering the immense importance of CT in all ramifications. Therefore, this research aims to determine the CT skills of Physics teachers in inquiry-based classroom in Kebbi state, Nigeria.

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II. METHODOLOGY

The descriptive research design is chosen to observe and describe the behaviour of the physics teachers in an inquiry based learning classroom. The study is carried out in some selected secondary schools in Kebbi state Nigeria among ninety (90) physics teachers from a population of 130 physics teachers that claimed to be knowledgeable of inquiry based learning constituted the sample of this study. The Lawson scientific classroom reasoning test is used as the instrument for testing the critical thinking skills of the physics teachers [58-61]. Table 1 illustrates the table of construct in which the evaluation aspect of the reasoning skills has the highest number of questions and the analysis aspect have the least number of questions.

Table 1: Table of Construct for LCTSR

Item	Question Number	Number of Questions
Analysis (proportional and probabilistic reasoning)	5,6,7,8,13,14	6
Synthesis (conservative and control reasoning	1,2,3,4,9,10,11,12	8
Evaluation (hypo-deductive and deductive reasoning	15,16,17,18,19,20,21,22,23,24	10

III. RESULT AND DISCUSSION

The test scripts were retrieved from the sampled physics teachers and marked out in percentages. The result obtained was keyed-in in the SPSS software in accordance with the construct of the test. The mean and standard deviation of the test scores for each construct is presented in Table 2.

Table 2: Critical Thinking Skills of the IBL Physics Teachers

S/N	Dimensions	N	Score Obtainable	Mean	SD	%
1	**Analysis**	90	30	9.33	5.47	31.1
2	**Synthesis**	90	40	9.50	4.68	23.8
3	**Evaluation**	90	50	7.50	6.41	15.0
Overall critical thinking skills		**90**	**120**	**26.83**	**7.40**	**22.4**

From Table 2, out of the supposed scored of 30 marks of the analysis construct of the reasoning test the physics teachers had an average score of 9.33 which equals to 31.1%. This indicated that the IBL physics teachers' responses to the questions on proportional and probabilistic reasoning was weak. The synthesis part of the reasoning test which comprises of control and conservative reasoning, the physics teachers have an average score of 9.50 which equals to 23.8% from the total obtainable marks of 40, this is equally a very weak performance. The worst performed segment by the physics teachers on the reasoning test is the evaluation stage which involves combinational and correlation reasoning, where the total obtainable marks is 50 and the physics teacher's responses is 15% which equals to an average score of 7.5.

The result of the three dimensions generally indicated a poor representation or perhaps misconceptions of the teachers in their reasoning abilities in the three dimensions (Analysis =31.1%, Synthesis =31.1% and Evaluation =15%) of the Lawson reasoning test. Similarly, in the overall reasoning skills of the teachers as indicated in the table 2 showed a very weak mean score of 26.83 which equals to 22.4%. The overall percentage of the physics teachers is

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below average. These findings indicated that the IBL physics teachers are not so good in the areas of evaluation (deductive reasoning) abilities as well as the Synthesis (control and conservational) parts of the reasoning test, they equally need to improve in all the parts of the reasoning test. In contrast with the findings of [56] who tested the pre-service teachers reasoning abilities in Ugandan college using the Lawson test and found that the pre-service teachers were good in the synthesis aspect but poor in a evaluation and analysis. But the findings of [57] on chemistry teachers reasoning skills in Kwani high school Ghana conforms with this studies. Furthermore, the teachers' responses to the questions can be zoomed in qualitatively as thus; it is expected of the teacher to confirm the experiment but most of the teachers did not attempt the questions which lead to low scores.

Figure 1 indicated a sample of the deductive reasoning question as given in the Lawson reasoning test.

The figure 1 below at the left shows a drinking glass and a burning birthday candle stuck in a small piece of clay standing in a pan of water. When the glass is turned upside down, put over the candle, and placed in the water, the candle quickly goes out and water rushes up into the glass (as shown at the right).

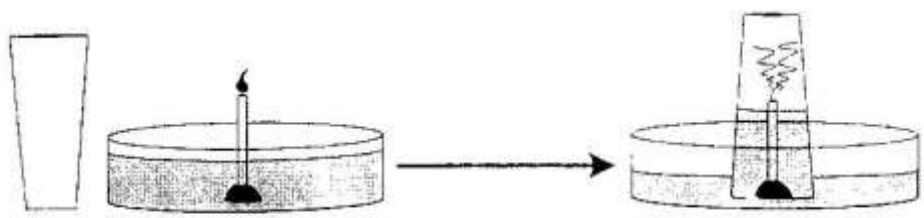

Fig 1: Drinking Glass, Pan of Water and Candle Stick

This observation raises an interesting question: Why does the water rush up into the glass? Here is a possible explanation. The flame converts oxygen into carbon dioxide. Because oxygen does not dissolve rapidly into water, but carbon dioxide does, the newly formed carbon dioxide dissolves rapidly into the water, lowering the air pressure inside the glass.

Suppose you have the materials mentioned above plus some matches and some dry ice (dry ice is frozen carbon dioxide). *Using some or all of the materials, how could you test this possible explanation?*

a. Saturate the water with carbon dioxide and redo the experiment noting the amount of water rises.
b. The water rises because oxygen is consumed, so redo the experiment inexactly the same way to show water rise due to oxygen loss.
c. Conduct a controlled experiment varying only the number of candles to see if that makes a difference.
d. Suction is responsible for the water rise, so put a balloon over the top of an open-ended cylinder and place the cylinder over the burning candle.
e. Redo the experiment, but make sure it is controlled by holding all independent variables constant; then measure the amount of water rise.

Figure 1: Deductive Reasoning Question 1

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This question is part of the deductive reasoning and Hypothetical-deductive reasoning Hypothetical-deductive method (HD method) is a very important method for testing theories or hypotheses. The HD method is one of the most basic methods common to all scientific disciplines including physics, biology, and chemistry. Its application can be divided into five stages:

a. Form many hypotheses and evaluate each hypothesis
b. Select a hypothesis to be tested
c. Generate predications from the hypothesis
d. Use experiments to check whether predictions are correct
e. If the predictions are correct, then the hypothesis is confirmed. If not, the hypothesis is disconfirmed.

Another interesting question provided in the Lawson test is shown in figure 2. Here the teacher is provided with an experiment and assumed to have the materials, he is expected to confirm the result of the experiment

The teachers' responses to this question are negligible. The same type of weak performances is noticed in the synthesis part of the test by the IBL physics teachers with a percentage marks score of 23. This is a test where the teachers ability to control variables is tested, for instance, a question in the Lawson's Test is as below;

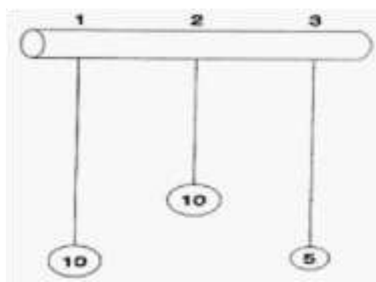

Fig 2: Strings with Hung Masses

Figure 2, above are drawings of three strings hanging from a bar.

The three strings have metal weights attached to their ends. String 1 and String 3 are the same length. String 2 is shorter. A 10-unit weight is attached to the end of String 1. A 10-unit weight is also attached to the end of String 2. A 5-unit weight is attached to the end of String 3. The strings (and attached weights) can be swung back and forth, and the time it takes to make a swing can be timed. Suppose you want to find out whether the length of the string has an effect on the time it takes to swing back and forth. Which strings would you use to find out?

a. only one string
b. all three strings
c. 2 and 3
d. 1 and 3
e. 1 and 2

Figure 2: Deductive Reasoning 2

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Note: In this problem, there are two variables that may influence the time it takes to swing back and forth: the length of the string and the mass of the attached weight. Teachers are asked to determine the relationship between the length of the string and the time it takes to swing back and forth, so the size of the weight needs to be controlled (held constant). The weights attached to the end of string 1 and 2 are the same, but the lengths of these two strings are different. They can be chosen to test the relationship between length and swing time.

The two examples are given to justify the teachers' weak performances in hypo-deductive reasoning, deductive reasoning control and combinational reasoning skills. It also buttresses the fact that the teachers' critical thinking ability is weak.

IV. Conclusion

Critical thinking is important to teachers and students not only in an inquiry-based learning classroom but also in the entire teaching and learning processes [62], Unfortunately the physics teachers in this type of classroom that is expected to increase the critical thinking skills of the students proves otherwise. It has been argued by [63] that Inquiry learning models has proven to contribute significantly to the scores of critical thinking skills on students, however, the physics teachers in this study have very low critical thinking skills, since both the female and the male physics teachers obtained very low mean scores in the classroom reasoning test. The implication is the argument forged by some researchers that the IBL can increase the CT skills of students becomes absurd. Teachers with low critical thinking skills in an IBL classroom may be defiant in passing a value judgement of the students' activities. They may equally be unable to portray the scientific attitudes expected of an inquiry mind. Therefore, there is need for teachers to engage into programs that will assist them to foster their deductive and hypothetic-deductive reasoning skills. The paper recommends for workshops to enlighten the IBL teachers on the impotence of critical thinking in education.

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