Penerbit Akademia Baru

International Journal of Advanced Research in Future Ready Learning and Education

https://www.akademiabaru.com/submit/index.php/frle/index
ISSN: 2462 - 1951


# Critical Thinking and Teaching Conception of Nigerian Physics Teachers in Inquiry-based Learning Classroom

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**ABSTRACT**

In as much as teaching is meant for attending people's experience and beyond then teachers must be ready to negotiate their conceptions to tally with the people's aspirations. This study revisited the long averted aspect of teaching (teaching conception and critical thinking) particularly in physics amongst secondary school physics teachers in Nigeria. Classroom observation and interview was conducted within a period of three months on a sample of 4 secondary school physics teachers who claimed to adopt the inquiry-based learning while teaching. The recordings were transcribed and analysed using content analysis method. The physics teachers were found to be more inclined towards the traditional method of teaching instead of the constructivist teaching method which serves as the main goal of teaching. A framework is therefore developed from the findings to assist physics teachers and educational planners to effectively implement the constructivist paradigm in physics lessons with particular reference to inquiry-based learning teaching strategy.

***Keywords:***
Critical thinking; teaching conception; inquiry-based learning; physics education

| **Received: 18 April 2024** | **Revised: 20 April 2024** | **Accepted: 22 April 2024** | **Published: 24 April 2024** |
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## 1. Introduction

One of the most important components of schooling is the teacher. An effective and willing teacher can successfully deliver a lesson regardless of the environmental condition [1,2]. However, the teacher may be deterred by certain caprices such as the teacher's belief of his/her area of specialization, teaching method employed, school environment, job satisfaction, attitudinal influence, values preference, incompetence and so on. These impediments are mostly neglected in current literatures, especially in physics education [3]. Good and effective teachers always have in their minds how they can succeed in their teaching, they always search for ways to make their teaching more effective and successful [4]. Unfortunately, current literatures discuss very little on the physics teachers teaching conception especially as it affects an active form of learning like inquiry-based learning [3,5]. Inquiry-based learning (IBL) is an active form of learning which ignite student's curiosity [5-10]. Physics subject encompasses laws, principles and theories that needs to be verified through

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active and collaborative activities, it may be easier for teachers to embrace IBL methodology for such goals to be achieved. Students learning in IBL classrooms remained retained since they lead the leaning activities [5,7,10].

Unfortunately, teachers often lack the guiding principle of its operation, the little that learnt about it failed to implement its practices in their classes especially physics teachers that presumably upheld the notion that science teachers are critical thinkers [10,11]. To this crop of teachers, they upheld the belief that physics teachers are critical thinkers and therefore, studying teacher's conceptions about their teaching or learning to think deep is not of significance [12,13]. Such belief can be argued to be erroneous since teaching and knowing are separable terms. Teachers can be knowledgeable but find it difficult to impart knowledge to others [14]. It is therefore the concern of this paper to elucidate and emphasize the urge to lay more emphasis on the teaching conceptions (TC) and critical thinking (CT) of physics teachers as potent tools to the enactment of IBL in Physics classrooms.

## 2. Literature Review

Researchers on teaching conceptions (TC) often refer TC as teachers upheld beliefs, intentions, values, attitudes, perceptions [15-17] and other educators refer TC as processes of teaching [18]. The study of TC is vital for teachers to clearly understand the orientation of the teachers, teachers' understanding of the subject, and teachers' relationship with their students, and teachers' ideology in terms of learning theory. Basically three learning orientations were identified by researchers [15-17] which are, the direct transmission/teacher centred, the student centred and the integrated centred approach. The direct centred approach is the traditional teaching method where the teacher is considered as the alpha and omega of knowledge. The teacher explains, demonstrates, and experiments with little or no internal/external support. The students in this class remained passive listeners. This orientation does not encourage critical thinking [17] mostly the teaching is egocentric [11,19]. Teachers usually skip some parts of the syllabus that seems difficult to them. The orientation encourages rote learning [20]. The teaching and learning becomes boring [14]. The student centred orientation is an active form of learning that gave freedom to students to explore and solve their problems collaboratively with little intervention of the teachers [7-10]. This approach encourages critical thinking [21-22] increase curiosity of the students [10,23] pleasing lessons (teachers and students are happy) [2] Learning in this orientation aimed at lifelong learning [10,20,23]

The integrated orientation is the mixture of the two orientations [24] when time permits, the teachers may decide to employ the student-centred orientation some other times used the teacher centred orientation. This orientation differs from the student-centred orientation in the sense that the constructed knowledge is operated based on the teacher's framework [16,17]. Research on teachers' TC is important because evidence from literature revealed that teaching conceptions affect teachers' choices of teaching method and learning activity, the number of classes/lessons, and the school environment, where all of these directly affect the student learning. These were confirmed in the studies of Peck and Cavlazoglu [4,25]. Some literatures that contributed in this part of the study includes the study of Ross [26] that identified 25 different teaching conceptions in his studies on conceptions in teaching an illustrative review. Tavakoli [27] investigated teachers' conceptions of effective teaching in Iranian high school and examined the relationship of those conceptions to their teaching practices. The authors used questionnaires, observation, and interview as their research instruments. The result indicated a high consistency between the teachers' conception of effective teaching and their corresponding teaching practices. Martin *et al.*, [28] studied the conceptions of infant, primary and secondary school teachers in Spain. The study identified many upheld teaching conceptions which according to them are more pronounced at higher level of education. To concur with the studies on teachers' conceptions of plant they found that college teachers considered student's perspective while university teachers concentrated on their own view points. That is why teachers of the traditional orientation teach physics to students by strictly following the textbook instructions, only the examples in the text books will be given to the students without further elucidations. Laws, theories and principles of physics are crammed by rote learning, contrary to the constructivist's orientation which encourages physics principles and theories to be verified by the students through active participation and collaboration of the students. The review stressed the importance of teaching conceptions of teachers in learning environment, unfortunately, not much emphasis is laid on it in the current literature. This study is intended to breach this gap in literature by studying the physics teachers teaching conceptions in Nigeria.

Similarly, critical thinking which has a very long outcry by numerous educators, educational organizations and educational stakeholders have little recognition in Nigerian literature [29] The little that exists were mostly on the CT of students providing less attention to the student's groomers [2]. Critical thinking is inevitable in education; it is considered as one the purposes of literacy (thinking deep). Teachers that are considered as the nation builders need to be critical thinkers for a successful and effective training of critical thinkers. Critical thinking is about intellectual discipline, process of actively and skilfully conceptualizing, applying, analysing, synthesizing, or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action [30]. Researchers in CT has identified various contingencies that prevent the teaching and learning of CT of fundamental is the lack of professionals [31-33]. Nigeria is no exception. Very few teachers reported by literature are aware of what CT entails [11,34,35]. This may probably be due to the background training of which is mostly in the traditional orientation [35,36]. Scientists are presumed to be critical thinkers [37,38]. Unfortunately, many studies from literature [31,39] have confirmed the fallibility of the statement. For instance, Valdex [39] reported the Darwinian theory of evolution as uncritical in thought he further illustrated that most of scientific theories were developed by chance citing an example with Kekuke who was said to discovered benzene after dreaming of a snake biting its tail, and the discovery of many elements by Marie Curie.

Inquiry-based learning (IBL) is an active form of learning involving collaborative activities of the students with a little intervention of the teacher. Bundle of research have indicated its effectiveness on students learning [5-10]. Many countries transited from the traditional teacher centred approach to the more pragmatic and systematic student's centred learning like the IBL. Twelve European member countries were investigated and encouraged to the practice of IBL using Promoting Inquiry based learning in mathematics and science (PRIMAS) questionnaire and Mathematics and Science for life (MASCIL) questionnaire in 2011 and 2014 respectively. The United States of America also campaigned for the implementation of IBL through K-12, focus on inquiry programs, Similar efforts were made in Australia, Thailand, Singapore, China, Russia, Japan and other western world. Perhaps these transformations made them what they are today. Unfortunately, such strides were not reported by literatures of West Africa particularly Nigeria which is considered to be the giant of Africa [40]. Moreover, physics teachers are claimed to be objective in their thought and critical in their practices [41]. These claim is worth verifying n African continent especially Nigeria since it is considered as the Mother of Africa [40,42].

This study is particularly conducted in Nigeria due to the fact that Nigerian education is a traditional based curriculum where students are only groomed to pass an internal and external examination. Therefore, there is the need to investigate the Nigerian physics teachers teaching conception and critical thinking who practiced inquiry based learning in teaching and learning of physics in secondary schools. The study is important because physics teachers may be upholding some conceptions about their teaching methodologies that are making students to have phobia of physics.

It is evident that most of the Nigerian higher institutions are running short fall of students. The few that are there finds it difficult to relate what they learnt in the class with the world of works [43] The study may equally ignite the physics teacher's enthusiasm to implement IBL in teaching and learning of physics. The teacher's traditional orientation may equally change to the constructivist idea of developing teaching from the student's perspective.

## 2. Methodology

The study employed qualitative research design with the use of quantitative data to select the respondents of the research. A sample of 90 secondary school physics teachers [44] were purposefully drawn from a population of 120 physics teachers of some Nigerian secondary schools. To ensure the physics teachers have knowledge of IBL, PRIMAS questionnaire and situational judgement test (SJT) was distributed to the 90 teachers, best 10 respondents (physics teachers) were selected for classroom observation. The 10 selected respondents' sample of the Nigerian physics teachers were observed while teaching physics by using the Approaches to Teaching Inventory (ATI) [45]. The 10 physics teachers were duly informed about the non-participatory observation, every action the teachers performed with the students were observed and recorded using ATI and observation notes. This was done verbatim in addition to the signing of the consent form. The teachers were also told that everything is done for the purpose of research not to report them to the authority. By so doing the teachers felt at home. Based on the observation result, the best four physics teachers who demonstrated IBL were selected for an in-depth study through a semi-structured interview using an interview protocol. The physics teachers were made aware of the interview, they were equally assured of secrecy and confidentiality. They were asked of an appropriate place and convenient time for the conduct of the interview.

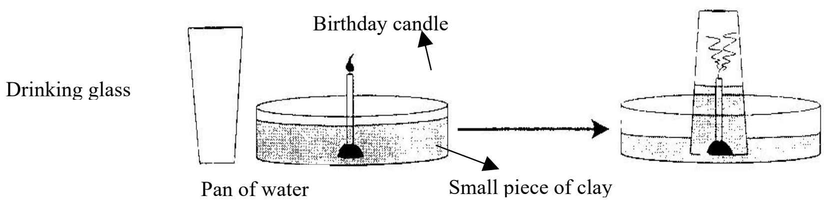
The physics teachers were observed while teaching in the classrooms. Some of the teachers were observed to be teaching in the traditional orientations following the scheme of work submissively, senior secondary 11 (SS11) classes were used, the choice of the class was due to their schooling experience, and such class has passed the introductory level but have not reached the echelon. In this class Kinematics was the general topic the teachers were teaching. Both the observation guide report and the participant's responses were transcribed, read and re-read to figure out meaning and understanding of the responses using coding strategy [46]. Descriptive coding was used for the observation because it is the reporters own statements while In Vivo coding was used on the interview transcripts [47]. The generated codes were huge, this demands for their screening, removing similar and overlapping codes through the process of open coding [47]. The codes are sectioned into categories such as; teacher's readiness, experience of learning environment, challenges related to resources, IBL practices, student centred learning, scientific reasoning, students generated questions and learning assessment challenges.

## 3. Data Analysis and Results

Four teachers were chosen for an in-depth study. The teachers were of 10-30 years teaching experience. All necessary protocols before the interview were strictly observed (permission from ministry, permission from the principals, teachers consent and assurance of confidentiality [46]. These participants were given a critical thinking test adopted from Lawson [48]. This test is subject specific, it is one of the only validated and widely recognized test of scientific reasoning [49] other test are mostly on certain courses of physics, for instance, Tiruneh [50] studied critical thinking skills in Electricity and Magnetism, and Mabruroh and Suhandi [51] on sound energy. The Lawson test questions (LCTSR) are in matching type test form and mostly deductive reasoning questions which encourage critical thinking. The matching type test questions measures originality, the ability to synthesize ideas, write effectively, or to solve problems [52]. The physics teacher's responses to the questions were fair on the knowledge analytic, and synthetic part of the LCTSR. The performances may not be unconnected with the nature of the questions. For instance, the questions on the knowledge construct of the LCTSR are aimed at testing the cognitive skills of the respondents since the knowledge of subject matter is of paramount importance in the illustration of CT [48]. Similarly, the questions on the analytic part of the LCTSR are basically on mathematical skills with specific reference to proportionality and probability. This is to encourage respondents on mathematical thinking skills which forms an integral part of CT [48]. In addition, the questions on the synthesis part of LCTSR are designed to foster into the respondents the ability to create, creativity is one of the characteristics of CT [48]. However, very poor feedback was noticed in the hypothetical deduction reasoning questions. Which can be argued to be discouraging considering the teaching experience of the physics teachers.

For instance, questions no 21 and 22 of the test aimed at deepening the understanding of participants' hypothetical deductive reasoning skills. This type of reasoning skills is encouraged in the field of science to increase logical and skilful analysis of phenomenon to arrive at a valid inference [53]. It always starts with a hypothesis. In this case, the participants were shown an experiment in form of demonstration, they are expected to engage themselves to explore the same inference as was demonstrated to them earlier. The hypothesis carbon dioxide dissolves rapidly in water was first arrived at during the first part of the experiment. The participants were asked to verify the hypothesis using the same materials shown in the demonstration. The following are the participants' responses; Participant A correctly chose the answer to Y but wrongly depended his choice of answer in Q22. Participant B and C wrongly answered Q21 but participant C rightly scored Q22

**Q21**. A drinking glass and a burning birthday candle are inserted 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 is removed and water rushes into the glass (as shown at the right).




Q21 of the LCTSR

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 and some matches as well as dry ice (dry ice is frozen carbon dioxide). Using some or all of the materials, how could you test this possible explanation? A and B must be answered together

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 in exactly 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

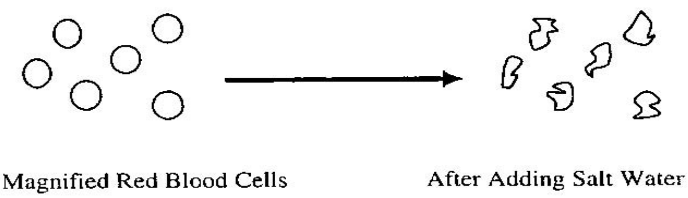
**Q22** What result of your test (mentioned in #21 above) would show that your explanation is probably wrong?

a. The water rises the same as it did before.
b. The water rises less than it did before.
c. The balloon expands.
d. The balloon is sucked in.

**Fig.1**. Questions no 21 and 22 of LCTRS

The responses to the questions are generally weak in this part of the test. This may not be unconnected with the participant's background knowledge which was teacher dependent [2,54] The participants were not encouraged to subject themselves to these analytical approaches to scientific questions. These type of questions are set to train the respondent to acquire deep thinking skills in order to make logical and scientific conclusions on matters. Logical reasoning skills and accurate decision making are elements of CT and are not demonstrated in the responses of the teachers to the questions. The responses could be argued to be a sort of guess work in the sense that the questions are two tiered type, an answer to the first part of the question is supposed to lead to the correct answer to the other part [48] unfortunately none of the participants correctly responded to the two questions. In a similar development the participant's responses to Q23 and Q24 of the LCTSR further illustrated their weakness in CT. In these questions experimentation, observation, inference and curiosity composed the aim of the questions in the LCTSR [48]. The participants performed below average perhaps due to the experimental nature of the questions, the physics teachers might have not come across such experiments during their school life, talk less of imagining how to have done the experiment in the absence of the tools. The question increases curiosity for it involves some local materials such as a plastic bags filled with water to represent the red-blood–cell membrane [48]. Curiosity is another characteristics of CT that should be possessed by all teachers of physics. Q23 was wrongly answered by all the participants and only two of the participants gave the right answer to Q24. The two correct answers given by the two participants could be argued to be a guess work since the two questions are tiered one correct answer leads to the correct response of the other question.

**Q23.** A student put a drop of blood on a microscope slide and then looked at the blood under a microscope. As you can see in the diagram below, the magnified red blood cells look like little round balls. After adding a few drops of salt water to the drop of blood, the student noticed that the cells appeared to become smaller. This observation raises an interesting question: Why do the red blood cells appear smaller?




Here are two possible explanations: I. Salt ions (Na+ and Cl-) push on the cell membranes and make the cells appear smaller. II. Water molecules are attracted to the salt ions so the water molecules move out of the cells and leave the cells smaller. To test these explanations, the student used some salt water, a very accurate weighing device, and some water-filled plastic bags, and assumed the plastic behaves just like red-blood-cell membranes. The experiment involved carefully weighing a water-filled bag, placing it in a salt solution for ten minutes and then reweighing the bag.

*What result of the experiment would best show that explanation I is probably wrong?*

a. the bag loses weight
b. the bag weighs the same
c. the bag appears smaller

**Q24.** *What result of the experiment would best show that explanation II is probably wrong?*

a. the bag loses weight
b. the bag weighs the same
c. the bag appears smaller

**Fig.2**. Questions no 23 and 24 of LCTRS

In fact, the responses to the LCTSR test by the participants is not encouraging on the ground that the test is most of the times administered to students of undergraduate [53] but administered to experienced practicing physics teachers that are supposed to have an excellent outstanding performance. This calls for an in-depth study to understand the physics teachers better. The participants were therefore, requested for an interview to further explore their understanding of conceptions and practices of inquiry. They were interviewed based on their IBL practices and the way they taught, the interview was recorded and transcribed line by line. The participants profile was first reported as thus;

**Table 1**
Participants' profile

| Participants | Gender | Qualification | Years of experience |
|---|---|---|---|
| Participant A | Male | BSc ED MSc Ed science education | 32yrs |
| Participant B | Male | BSc, MSc physics and PGDE | 27yrs |
| Participant C | Male | NCE, BSC Ed physics | 22yrs |
| Participant D | Female | B Ed physics | 15yrs |

Table 1 indicates that all the teachers are professional teachers, they equally possessed a great level of experience with none of them having less than fifteen years of working experience. One of the fundamental questions during the interview was on the participant's preparation to implement IBL in their physics classroom. The participant's responses to the question was complimentary even though they contested that their knowledge of IBL is not intense, because they only learnt about IBL during their undergraduate and were not chanced to undertake any professional training of IBL. Participant A said,

*Yes, we like using inquiry to teach just like we taught using demonstration, lecture and laboratory methods but we don't know much about inquiry, we learn inquiry only during our undergraduate studies which you know is not in-depth and uphill now we are not taught by any specialist in the inquiry and I like it because I will be less in talk unlike the class we used when we talk and talk continuously. it will be good if we can be taught how to do it well.*

From the respondent above the participants are ready to implement IBL they realised that IBL is a learning strategy that can even help them to work less in the sense that the teaching and learning has become student-centred. Students does most of the work while the teacher guide and instil discipline.

School environment, the school administrators and the students all played a vital role in the learning environment and the teachers The participants shared their views on the school administrators view on using IBL as a teaching method in their physics classrooms, they were equally asked of their relations with other colleagues towards assisting them when conducting IBL likewise the participants were asked about the student's ability to comply with the method. The participant C responded thus.

*We have never been stopped by our administrators on the method we employed when teaching our students rather we are even encouraged, our concern is just the time because IBL consumed much time when implementing it and the time allowed on the time table is only forty minutes, the time is not enough. So we only managed sometimes because of the students' population I have to ask some of my friends to assist me in controlling the students because they make a lot of noise when asked them to do any group work, so with the assistance of my friends we bring them to order, you know students when you allow them to interact among themselves some will make the session happy some will not allow others to do the work but they always like that. you can see it on their face because everybody is laughing. Sir, do you know that there are schools that don't have laboratories to conduct practical and they offer physics and chemistry. Can you imagine how they trained the students? You will agree with me the situations are terrible'*

Here the participants praised the school administrators by exonerating them from any sort of interference during the discharge of their job. They also indicated their cooperative concurrence with their colleagues when it comes to work. The joint action of the participants in conducting their lessons successfully is considered a landmark in teaching and learning. It is an action worth emulating, the students also learnt to do collaborative activities since they saw their teachers practicing the same. The unfortunate scenario is the issue of schools that don't have laboratories and are offering science subjects. The method of teaching physics in such schools is worrisome. The participants expressed their reservations on implementing IBL such as experimental equipment for conducting practical activities. Participant B said when asked about how the resource were used in an IBL classroom.

*'Materials to be utilised are very scarce because if you teach students, you need to make available the materials that are required in teaching and learning process. So, these materials are inadequate whereby, if you want the students to share, you have to make large group and you know making large groups required excess time energy and difficult to control especially young adults like the ones you saw'.*

The participants expressed their fear of lack of enough materials in the laboratories for conduct of practical activities during their IBL classroom. The little they have cannot go round the groups, unless large groups are formed which often made the exercise chaotic and dreary. IBL is an activity based method which cannot be negotiated with mere discourse. On the IBL practices the participants were asked about their role in IBL classroom, Participant A said

*'I may decide to guide them all together or I may leave them alone. But as regard to my classroom situation because of the fact that sometimes, if you leave the students alone, they may end up wasting time without getting the desired result. So, in this regard I always have to be together with them guide them. Wherever there is problem, I will assist them to the best way to arrive towards a solution'.*

Participant A was expressive, He contended that depending on the topic of discussion and possibly the time available to him, he can be with the students scaffolding them in the activities and other times allow them to do all the activities. Depending on the skills and ability of the students, an IBL classroom demand for guidance from an expert. But when the participants were asked how they asses their students in an IBL classroom participant D said

*'There are so many ways that we can evaluate and understand whether the students are getting the desired objective or not in the learning process. As there are many ways of evaluation or evaluating the students, I will decide to use either test examination or assignment in order to find out how far the students have gotten the piece of instruction given to them. Often, the most reliable source used is examination and test in order to evaluate how far they have achieved with regard to this particular piece of instructions. Therefore, examination and test are what I used formally as my evaluation of content to the students'.*

This participant although is an experience teacher yet prepared the use of the traditional method of assessing the student but assessment in IBL is not summative. It is concern with long term understanding aimed at achieving a lifelong learning while traditional form of assessment is limited to short term goal besieged at either promoting from one class to another or school leaving certificate. These categories were used to design a framework as in Figure 3 which may serve as a guide to education planners, physics educationist and physics teachers.

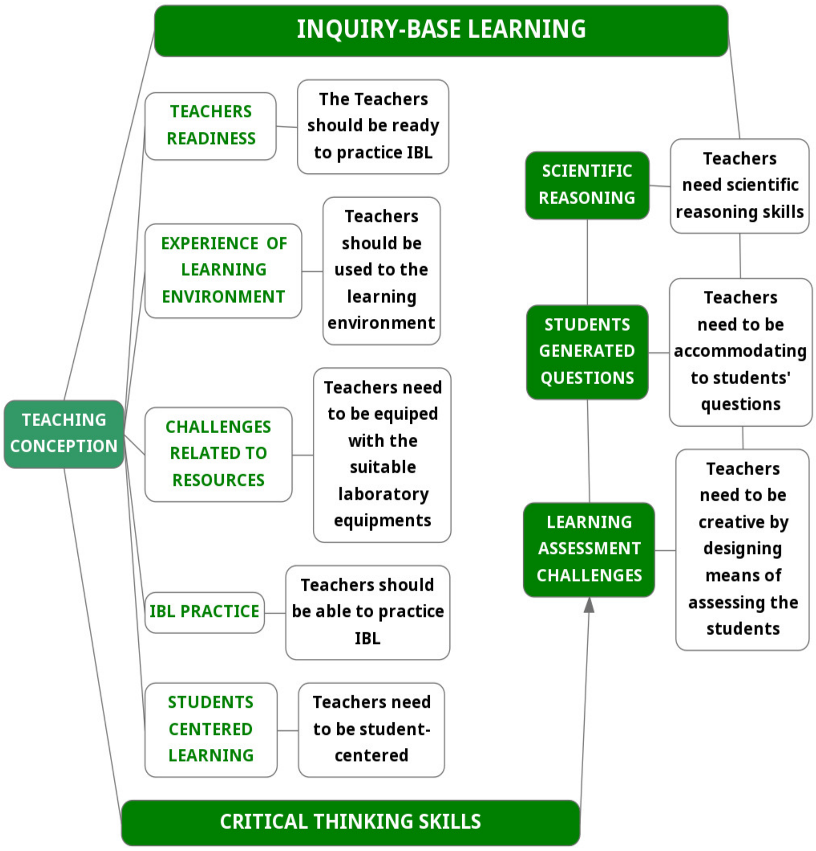



**Fig. 3.** The critical thinking and teaching conceptions framework

Figure 3 showed the framework that emerged from the data. Critical thinking and teaching conceptions yielded a number of issues that the teachers faces while practicing IBL. All the issues were raised by the participants during the interview, observation and the critical thinking test. The issues were coded and simplified to form categories. On teachers' readiness: to practice IBL, the participants expressed their willingness to implement IBL in their classroom although knotted with shortage of technical knowhow of what IBL entails. They claimed to learn about IBL during their undergraduate which shows their microscopic knowledge of IBL. They emphasized that they have not undergone any form of professional training on IBL which might have boost their morale to implement and practice the method. Even though the study of Minner [23] and García-Carmona [10] reported a non-uniform format of IBL practices.

Challenges related to learning environment experiences are enormous since some teachers often expressed their difficulties of accommodating and assimilating new environment. Teacher needs to make a fresh preparation of relating with new students, new laboratory and new administrators whenever posted to a new environment, this usually takes time, teachers transfer from one school to another has a devastating effect on the teacher's effectiveness [2,14,55]. Some schools are in short of laboratories which may necessitate the teacher to start all activities from the scratch which may invariably takes a lot of time. Other teachers could not manage large classes. Overpopulated classes are sometimes difficult to handle, teachers with large class size face difficulties of class control and discipline [2,14,55]. Challenges related to resources: this section provided a summary of the resources related challenges the teacher faced while delivering lesson in the IBL classroom. Teachers usually complain of lack equipment to practice IBL, some said the materials are inadequate, while others reiterated that there are no materials at all to practice IBL in their classroom. IBL is activity based method that requires the use of a lot of material resources that will encourage the students to delve into hypothesis testing, theory, principle or verification of physics laws [14,42]

For the teacher to practice IBL in the classroom the teacher requires adequate knowledge of IBL availability of teaching aids, laboratory, time and commitment of the teacher'. Some of the participants are up and doing with the assistance of their school heads to implement the method whenever the need arises. They stated that it is not all the times they use the method because of the provision of the school syllabus. Furthermore, the participants preferred to use the guided inquiry method amongst other types of inquiry, although one of them considered using the true inquiry method, unfortunately, there is no enough tooling for the students to be left unguided. The teacher's knowledge of IBL is paramount [2,14,23,55]. He should be able to demonstrate the nature and type of IBL used in the classroom and assess the most effective and convenient to be use considering the level and ability of the students. One of the most challenging aspect to both the teachers and the students is this aspect of student-centred Learning. The teacher was trained and brought up in the traditional learning environment, it becomes difficult for the teacher to adjust to the new scenario where the student leads the discussion while the teacher stands to guide [12,13]. Similarly, the students felt uncomfortable because they were used to be spoon fed, they were always passive in the class, but in the new situation they own their learning. Although sign of excitement can be seen on their faces indicating their acceptance to the inquiry approach. This section expressed how the students felt in an inquiry classroom, what activity they partake and what are their total experience in the classroom when taught using inquiry approach.

Scientific reasoning: one of the aim of IBL is to develop critical thinking skills (13,23]. The teacher need this skill to be able to guide the students towards lifelong learning, active participation in solving problems of physics as it relates to the society. Inculcate in the students the ability to make valid judgements of phenomenon. The ability of the teacher to convince the students about the mystery of physics, facts and fallacies. By so doing the students will appreciate what they are studying and be able to convince others as well as apply the phenomenon to different situations.

The teacher need to condone the student's questions in order to encourage curiosity in the students [2]. The teacher should also ask the students challenging questions that will make every student to participate in the discussion. The students generated questions are questions often poised by the students to the teacher, sometimes the question may sound challenging to the teacher because he least expects such question from the student, yet the teacher professionally and confidently attend to the students question without discouraging the student by way of stunting the student with unnecessary commands. This summarizes the students questioning techniques in the IBL classroom, what are the nature of questions asked during their conversation with their group members? What kind of questions were asked by each member of the class and finally the type of questions asked by the teacher? classroom. The teacher need to develop more cogent ways of assessing the students in an IBL classroom contrary to the traditional way of assessing the students which was mainly aimed at certification. The participants emphasised on writing examination, test and assignments to evaluate students learning in their IBL classroom. Examination and test are mostly discouraged in an IBL classroom [9,22,23] perhaps assignments and observation may be employ to assess the progress or otherwise of the students. IBL is not examination centred, the participants expressed their concern, due to the traditional positivist orientation where examination is always emphasized, and some teachers held the notion that IBL cannot be examine and therefore cannot achieve the goal of learning.

## 4. Discussion

The current developments of the series of industrial revolution is a threat to the education industry that required a total overhaul of the type of educational skills we impart to the young ones. Unfortunately, the participants expressed curriculum designed in the Nigerian system of education as a menace to the success of gaining scientific skills of students. The curriculum they considered as encouraging teacher-centred conceptions, is a situation where the teacher is assumed to be the repertoire of knowledge [56]. The teacher's target in this type of curriculum is to complete the given syllabus within the time frame through knowledge transmission of facts [9,57]. But why are students still failing external exams? The students are only engaged in copying and memorizing of laws and theories. The expressions of the participants may perhaps be unconnected with the importance the Nigerian curriculum placed examination as the only yardstick for measuring students' performances [42,58]. In fact, teachers are evaluated based on the number of students passes in the national external examinations [42]. A teacher might be good but since the students were not able to pass the external examination the teacher is considered as incompetent teacher, this bigotry includes the school the teacher teaches [42,58-60] Therefore, physics teachers in an IBL classroom in Nigeria must complain of encountering a lot of challenges due to the curriculum orientation and the teachers' confession of not having professional training in IBL. But IBL has been confirmed to be an effective teaching method by different countries in the world [23,61] the teacher is expected to be focused and ready to accept changes that are aimed at achieving the societal goal. This he can do by continuous reading and attending conferences and workshops. Based on the participant's experience, they confessed that they should be having in-service training to update their knowledge on IBL pedagogies. This entailed their fear on the implementation of IBL since their knowledge of its pedagogical practices is insufficient, although the result indicated their readiness to blend the methodology in their teaching activities. These participants admitted that they only read about inquiry-based learning during their undergraduate courses but had no professional training on its modulus operand. Teachers tend to teach the way they were taught [62]. The teachers need to be introduce to various models of inquiry they need to transfer from the traditional teacher-centred to the constructivist orientation.

The participants also expressed another difficulty faced when trying to implement IBL as the time allocated for a lesson. The timetable being the mirror that reflects the entire educational programme of the school [60] has to be designed to ensure equitable distribution of work among teachers to avoid redundancy and duplication of activities. Timetable in the school system is designed to allow a smooth flow of the series of subjects to be learned everyday within the stipulated time allocated for the subject teachers [12]. Unfortunately, the participants expressed their objections on the allocated time as insufficient to undertake an IBL form of classes, because according to them, the session requires a lot of time for its preparation. Perhaps that might be the reason for arranging extra classes during the conduct of this study in order not to interfere with their normal classroom lessons and also to have enough time for the demonstration of their IBL knowledge and understanding. Moreover, the comments by the participants on the interview excerpts is a clear testimony to the anxiety of the participants on the timetable as an obstacle to implementing IBL in the physics classroom. The constructivist paradigm emboldens scaffolding base on experience of the student therefore learning can be done at any time and at any place.

These difficulties are equally shared by other researchers in IBL implementation as acknowledged by Blanchard [63]. Three of the most pressing concerns as reported by teachers while implementing IBL were: time, resources, and lack of teachers' preparation. Osborne [64] shared similar expression that in IBL classroom, teachers are often faced with numerous challenges such as teachers pedagogical understanding of IBL, time constraints and resources. These authors coincidently established what the physics teachers in Kebbi state expressed. Similarly, the CT hypothetical deductive reasoning questions are encouraged in the sciences to poster in-depth thought of phenomenon through various perspectives [49,65]. The computed Lawson test result of the Kebbi state physics teachers was found to be on average. The result of the finding corresponded with the result of [41,55,66,67]. This result indicated that the teachers were average in this aspect of thinking. The result has tallied with that of Ekwemasi [68] but in contrast with that of Diff and Tache [41] whose findings were students that showed astonishing performances on hypothetical deductive reasoning compared to probabilistic and proportional reasoning skills. Teachers need to be introduce to the variety of CT models that encourages Socratic form of questions that heighten curiosity and inquisitiveness in students.

The overall critical thinking skills of the Kebbi state physics teachers was found to be moderate. This could be said to be fair in the sense that it gives the physics teacher an opportunity to identify weaknesses and possible solution towards alleviating those problems rather than making him have the feelings of master of all. This result was corroborated by various studies of critical thinking using the Lawson classroom test such as the [49,65,68-70]. The result of the findings on Kebbi state physics teachers revealed their readiness to learn in order to boost their critical thinking capabilities. It also means that the physics teachers can moderately look at problems from all angles and provide alternative solutions.

## 5. Conclusion and Recommendations

This study encourages teachers of physics to be well prepared for the challenges of the series of industrial revolution challenges that are already becoming a menace to the education sector. The findings of this research study are important because they showed the need for revolution of curriculum from teacher-centred curriculum to a student-centred curriculum. There has been consistent criticisms on the inability of teachers to bring changes in the achievements and enrolments of students in external examinations and higher institutions respectively [71-73]. In this study, it was found that the student-centred method of transmission may curb these challenges, therefore, stakeholders and curriculum planners should as a matter of urgency include and mandate the use of IBL as a teaching method in all secondary schools of Kebbi state.

This study provides the stakeholders and curriculum planners with a modality of encouraging the physics teachers to use IBL methods while teaching physics in their classroom. The framework suggested for teachers' readiness, teachers must be ready to accept IBL as a better teaching method, it requires an adequate provision of laboratory equipment, laboratory equipment are very essential in IBL practice, it encourages a good learning environment for the teachers and students, it encourages teachers tolerant to student's inquisitiveness, in IBL classroom students will tend to ask a lot of questions to the teacher. The framework also encourages teachers to be open minded and creative in designing assessments methods to the students contrary the central examination system. Similarly, teachers should be provided with intensive training on the pedagogies of IBL to ensure adequate implementation. Curriculum planners may consider increasing the timing for a lesson which used to be 30-40 minutes per lesson to cater for inquiry classes. Issue of large classes needs to be given attention by way of constructing more laboratories and equip the laboratories with physics equipment that will be sufficient for the number of students, and this will encourage the spirit of creativity in the students.

Proper attention should be geared towards instilling CT skills of teachers of secondary schools, since critical thinking has been included as one of the objectives of Nigerian education [54,74]. The national policy on Education as well as curriculum planners, stake holders of education and principals should direct teachers to integrate critical thinking skills into classroom experiences. This may serve as a strategy that can yield a citizen that will be prepared to solve the myriad problems of daily living at all levels. This include challenges due to cybercrimes, educational bankruptcy and brain drain. The hope is that Nigerians will find meaningful solutions to the nation's scientific, technological, economic, social and political problems confronting the nation. Furthermore, critical thinking should be made compulsory for all secondary school's curriculum, scheme of work preparation and lesson plans when teaching as teachers will understand the concept better before imparting it to students. CT models are variant, teachers should be introduced to these models and their applications in different topics of physics so that the students can relate their learning experience with the world of works. Challenges of industrial revolutions can be accommodated with ease when teachers encourage students of physics to relate what they learnt in the classroom to the world of works. This study used Lawson classroom test for scientific reasoning [48] to assess the thinking skills of physics teachers because there was no general physics instrument for measuring thinking skills of physics teachers. Specialist of physics are hence challenged to as a matter of urgency develop a validated instrument that measures the CT skill of all aspect of physics.

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