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Exploring the potentials of collaborative learning activities of problem-based learning in teaching and learning chemistry in Nigerian secondary schools

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Abstract

Objectives: To explore potentials of collaborative learning of problem-based learning, its effects in promoting higher-order thinking, improved learning and skills development in Nigerian chemistry students.
Methods/Statistical analysis: This study adopted a qualitative method with an exploratory design. Two teachers and ten chemistry students (average age of 18) were selected purposefully from one Senior Secondary school (10 grade) in Yola, Nigeria as participants. The students went through four weeks of learning process using problem-based learning module. Data was collected through observations and student focus group interviews after the learning sessions. The data was transcribed, triangulated and analyzed based on content analysis.
Findings: The findings revealed that students experienced several collaborative learning activities including: setting their learning goals and worked together in small groups to achieve the common goals, sharing knowledge between them through presentation and teaching one another and assessment of self and peer. Teachers also assess individual students and group achievements, providing students with content knowledge and developing their prior knowledge through facilitation. The learning process generated an average frequency of 35 collaborative activities per hour. This frequency is more than the 24 activities per hour reported by research. These activities therefore generated optimum learning interactions between students and teachers and promote higher-order thinking, improved learning and skills development. However the finding also showed that the 35 collaborative learning activities per hour is less than 69 higher-order collaborative learning activities per hour as reported by research from developed countries. The low activities of the problem-based module learning process may be due to long time practice of traditional lecture methods, students 'low level of maturity and differences in learning environment between developing Nigeria and the developed world.
Application/Improvements: The researchers suggested for implementation of collaborative learning approach of problem-based learning in teaching and learning chemistry in Nigerian Secondary Schools to promote higher-order thinking, improved learning and skills development.
Keywords: Chemistry; Collaborative learning; Potentials; Problem-based learning; Teaching.

1.0.Introduction

Content knowledge can no longer address the 21st century challenges, graduates need to develop high-orders thinking skills and improved knowledge. Therefore, the focus of global science curriculum has shifted from teacher-centered learning to students-centered learning approach to produce graduates with higher-order thinking and problem solving skills. Encouraging students' participation and freedom to interact with teachers and peers are important components of the learning process. These have been advocated as the main strategies to stimulate high-order thinking [1]. Science curriculum should therefore be implemented through students-centered learning methods; learning activities should be adequate to promote effective learning, skills development and should be linked to real-world situations. An effective learning method should facilitate collaboration between students and activity-based to develop students higher-order thinking and problem solving skills [2, 3]. As a result of increasing

demand for producing effective graduates, educational planners become more interested in researches on effective learning strategies. Thus, the national policy on science education in Nigeria directed that science graduates should be equipped with improved knowledge and higher-order thinking skills to empower them for effective performance at various levels for national development [4]. Therefore, science teachers should promote improved learning and skills development through activity-based learning methods to produce effective graduates into the competitive society[5,6]. Students-centered learning approaches are implemented in most developed countries for 21stcentury education; therefore a change from traditional lecture method to activity-based learning approach is mandatory for Nigeria to have qualitative education that produce graduates with higher-order thinking skills, improved knowledge and other problem solving skills[7].

1.1. Teaching and learning in Nigerian secondary schools

Students, and teachers, activities are very important aspects of learning in any science classroom. Examples; teacher's questioning evaluates students' understanding, reinforces factual knowledge and elicits prior knowledge.It also stimulates student critical thinking and promotes classroom interactions as well as student participation in numerous other learning activities. Other teachers' activities include assignments, demonstrations of experimental procedures, intrinsic and extrinsic motivations. Students' questioning, presentation of ideas, participation in group discussions & experimental procedures, writing main points of instructions, individualized reading etc. are also vital activities for effective learning and skills development [1,8]. However, in conventional Nigerian chemistry classrooms, students and teachers activities are very low and cannot support development of high-order thinking skills. This could be due to traditional lecture methods and poor learning infrastructure [9, 10]. The traditional teacher-centered learning approach is still being practiced in Nigerian Secondary Schools. Teachers dominate the entire learning process with "lecturing and writing on the board" and considered their roles as dispensers of knowledge and the learners listening role as good manners and respect for their teachers. This learning approach does not give student the opportunity to express their ideas, interact with teachers and peers during the learning process. The students are essentially passive listeners; they occasionally ask very few questions. They solely rely on teachers for all information, instructions and explanations. The students lack higher-order thinking skills as a result of in-activities and low rate of interaction among them in Nigerian Secondary Schools chemistry classrooms [7].

1.2. Problem-based learning (PBL)

PBL is a constructive learning approach where students take the responsibility of the learning process by solving real-world problems through self-directed and collaborative learning activities with the help of a teacher as facilitator. The application of real-world problems to stimulate group learning and searching for relevant resources across disciplines facilitates students' development of higher-order thinking skills and improved knowledge [11,12]. PBL is supported by constructive and cognitive theories of learning [13, 14]. Itcomprises of seven (7) steps: Identifying real-world problems, exploring students' prior knowledge, generating hypotheses, and identifying learning needs, self-directed study, re-examination and application of new information on the problem, evaluation and reflection on learning process [12, 15].

Research reported the effectiveness of PBL in learning to include; helping students to take over the responsibility of the learning process as they learn though construction of knowledge by problem solving in groups under teachers support as facilitator and it improves the quality of learning because it cut across disciplines[16, 17]. PBL graduates are capable of applying knowledge and problem solving skills in solving practical problems in the society. This provides linkages between educational institutions and their host communities[18,19]. The PBL graduates' profile includes knowledge, skills and good attitudes because they went through activity-based approaches of learning by doing & teaching one another in social groups. PBL motivates and challenge students to construct knowledge by themselves. It is effective for Secondary Schools and higher educational institutions, therefore the focus of educational researches in 21st century [20,21].

Similarly, higher learning activities are reported in developed countries where a teacher asked 69 higher-order questions in one hour of activity-based learning process [22]. Research also reported [23] that, teacher put across an average of 24 questions per hour, which is substantially lower, compared to 69 questions asked by the western countries practicing activity-based learning approach [22]. However, conventional Nigerian chemistry teachers do not pose higher-order questions that could facilitate students higher order thinking. Research also reported 82% of low-order teacher questioning activities in Nigerian Secondary Schools; this is not good enough for chemistry classrooms [6]. The teachers' authority and control in traditional science classroom, limited students' freedom to ask questions

and interact with both teachers and peers in the learning process. Conventional Malaysian and other western students are also very weak in questioning activities during learning process, an average low rate of 2.6% and 1.1% student questioning were reported [23,22]. In order to stimulate adequate learning activities that developstudents' higher-order thinking skills, improved learning and other problem solving skills, activity-based learning approach is necessary for Nigerian Secondary Schools and tertiary educational institutions[7].

1.3.Problem-based learning activities

Collaborative learning motivates students to be actively engaged in discussing their ideas and experiences in the learning process by presentations and interactions with peers in small groups. It places the responsibility of learning on them. This gives students the ability to accept other people's viewpoints and collaborate successfully with other from different backgrounds to have improved learning and development of problem solving skills. Research emphasized the quality of group learning outcome as a reason for the success of collaborative learning process where students set their learning goals, work together in groups to achieve common goals, shared ideas and experiences through teaching one another, freely ask questions to teachers and peers and evaluate their own learning outcome under teacher's guide. The teachers as facilitators of collaborative learning need to design some learning activities which need collaboration, so that the success of one student is connected with success of others in the group for positive interdependence [24, 25].

Self-directed learning required students to manage their learning activities and work personally to acquire HOTS, flexible knowledge and other problem solving skills. It comprises different students-teachers activities such as self-guided reading, students' participation in group studies, searching for interdisciplinary resource and information from the internet and reflective writings. Teachers' activities include encouraging and motivating students learning, assessing students learning outcomes, and facilitating students' creative thinking. Learners' autonomy is a key concept in self-directed learning; however this does not mean learning without interaction with peers and teachers[26]. The context of self-directed learning has changed with the advent of e-learning, due to availability of more learning technology, private learning experiences and more sources of information that were hitherto not available[27].

2.0.Objectives

This study aims to explore collaborative learning activities of PBL module learning process in Nigerian Secondary Schools and the effects of such activities in developing HOTS, improved learning and other problem solving skills. It investigates the following questions:

(i) What types of activities are involved in collaborative learning?

(ii) How frequent are these activities per hour of learning?

(iii) How adequate are these activities in development of students' higher-order thinking skills, improved learning and other problem solving skills?

3.0.Methodology

The research adapted a qualitative approach with an exploratory design. Ten(10) chemistry students (average age of <18) and two teachers were selected purposefully from a Senior Secondary School in Yola, Adamawa State of Nigeria as research participants. The participants were introduced to the principles and practices of PBL by the researchers. The teachers carried out the PBL module learning process to the students for a period of four (4) weeks. The data was collected through direct observations during the learning process and interviews of a focus group of 5 students after the process to make a comprehensive description of collaborative learning activities based on the purpose of the study. The observations and interviews processes of the learning process were recorded. The improved observation field notes and interview transcripts were coded, triangulated and analyzed using content analysis.

4.0. RESULTS AND DISCUSSION

The quality of group outcome determined the success of collaborative learning. Facilitators of collaborative learning need to design a wholesome activity that requires collaboration and students positive interdependence

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[24].Observation field notes of the PBL module learning process reported the components of collaborative learning, describing collaborative learning activities done by students and teachers using students FILA chart. This chart is redesigned to integrate the learning activities into PBL stages as show in Table 1.

Table 1. Types of Collaborative learning activities

FILA Chart	Types of collaborative learning activities	Description of students and teacher activities
Facts	Teacher provides content knowledge to students.	**Teacher activities** The teacher introduced the problem and prepared an open climate for PBL environment. He encourages students to critically think and identify it.Teacher introduced the students through instructions to the group social skills for effective collaborative learning.
	Students work together as a team to achieve a common goal.	**Student activities** The students observed the problem critically on these questions: what is the nature of the problem? Why is the blockages and other problems?How do the problem manifest? Is it from water or pipelines? The students discussed on the questions and eventually assumed that the problem is due to pollution or hardness of water, but not from the pipe-lines.
Ideas What do we know about the problem?	The teachers elicit for students previous knowledge and builds on it during the process of learning.	**Teacher activities** From the fact available about the problem the teacher put across some motivating questions to the students: What do you know about the problem? How does it affect people and properties? The teacher forms some mixed ability students groups and introduces them to group social skills for effective collaboration.
	The students shared knowledge about the problem among them.	**Student activities** The students critically observed and discussed in their groups the issues around the problem through sharing their prior knowledge and experiences and make some assumptions that: The problems are due to water pollution. It is course by the presence of some chemical compounds in water. It is a large scale problem because most type of surface water is polluted by chemical compounds.
Learning issues What do we need to know? (Information & resources).	Teachers evaluate individual students' performance and groupsachievements.	**Teacher activities** The teacher posed some stimulating questions to facilitate learning. What do we need to know concerning the problem? What resources or new knowledge do we need to address the problem? The teacher guides students' group discussions to focus on their hypotheses through questioning.
	Students set their learning goals Students working together to accomplish task.	**Student activities** The students classify the problem into parts. They discuss in groups the specialty of each part. Students draw three working hypotheses on the problem solution (the learning goals). What courses these blockages and domestic washing problems? How do these problems affect human beings, house hold activities and other properties? How is hard water soften? The students resolve on how to get the new knowledge and assign tasks to each group member based on their working hypotheses. (Self-study & search for information)
Action plan What do we do?	Teachers assess individual students' presentations on the new knowledge.	**Teacher activities** The teacher motivates students to brainstorm and discuss on the new knowledge through individual and groups presentations the usefulness or effectiveness of the new knowledge and proffer solution to the problem.
	Students assess their learning and that of their peers. The students and teacher assess the effectiveness of the group product (new knowledge) as a solution to the real-life problem.	**Student activities** The students reconvened in general class after individual task. They brainstorm and discuss in groups through individual and groups presentations the usefulness or effectiveness of the new knowledge for application on the problem. The student integrate the acquired the new knowledge with prior knowledge, evaluate, analyze and apply on the problem for solution.

Table1 illustrates how student and teacher activities provide students content knowledge and worked together to accomplish task under the "facts" about the problem of the FILA chart. The activities also described how teachers elicits for students prior knowledge and build on it. How students share knowledge under "ideas" what do you know about the problem? The Table also described how teachers evaluate individual students learning and students groups achievements, how students set their learning goals and worked together to achieve the goals under the "learning issues" what do we need to know about the problem? It is also clear from the "action plan" of the Table what do we do to solve the problem? How teachers assess students' new knowledge and how students reflect and assess peers on the effectiveness of acquired new knowledge as a solution to the real-life problem.

4.1 The frequency of learning activities

The frequency of learning activities is an important factor in learning, the quality of instructional method increases with the increase in frequency of students learning activities. Students' participation in the learning process also promotes higher-order thinking and a better understanding of scientific concepts. Observation field notes reports the sum of frequencies of each type of collaborative learning in a complete PBL cycle of 4 hours conducted in two weeks as illustrated in Table 2.

Table 2. Frequencies of learning activities

Types of learning activities	**Types of collaborative learning activities**	**∑f**	**f/hour**
Collaborative learning activities'	Students and teachers factual statements	19	4.75
	Students share knowledge by teaching one another.	15	3.57
	Teachers provide students with content knowledge and also build on their prior knowledge.	12	3.00
	Students work together in teams to achieve common group task (group discussions).	25	6.25
	Students set their learning goals to guide them.	11	2.75
	Teacher evaluation of individual students and group learning.	21	5.25
	Students' evaluate their own learning and that of peers.	13	3.25
	Students moment of confusion	14	3.50
	Students discussions on irrelevant issues	10	2.50
	Total	**140**	**35**

Table 2 illustrates the average frequency of collaborative learning activities of 35 activities per hour. This is more than the 24 activities per hour reported by [**23]**. The collaborative learning improves students' activities and participations in the learning process. However, the activities are far below the 69 higher-order activities per hour from the developed countries [**22]**. The low activities of the PBL module may be due to long time traditional lecture methods, students 'low level of maturity and differences in learning environment between Nigeria and the developed world.

4.2. Order of Learning Activities

Higher order thinking skills involve learning of very complex skills including critical thinking and other problem solving skills. They required higher cognitive learning than lower order thinking skills, but they also have more important benefits to learners. HOTS involved synthesis, evaluation and analysis thus required activity-based learning method [5,6]. Table 3 illustrates the order of learning activities.

Table 3. Order of learning activities

Order of learning activities	Description of collaborative learningactivities	∑f	f/hour	%
Higher-order thinking	Teacher assessment of individual students and group learning.	21	5.25	15.00
	Students share knowledge through teaching one another.	15	3.57	11.00
	Teachers provide students with content knowledge and builds on their prior knowledge.	12	3.00	08.60
	Students work together to achieve a common goal through group discussions.	25	6.25	18.00
	Students set their learning goals to guide them.	11	2.75	08.00
	Students' evaluate their learning and that of peers.	13	3.25	09.29
	Total	**97**	**24.25**	**69.28**
Lower-order thinking	Students and teachers factual statements	19	4.75	13.60
	Students moment of confusion	14	3.5	10.00
	Students other personal life discussions.	10	2.5	07.14
	Total	**43**	**10.75**	**30.71**
	Grand total	**140**	**35.00**	**100**

Similarly, observation field notes reports of this research shows that collaborative learning generated 69.28% higher-order learning activities, this is similar to the 69.00% higher-order thinking activities from developed countries [22]. It is also clear from Table 3 that collaborative learning generated a low rate of low-order thinking activities of only 30.71%, compared to the range of (72-82) % lower-order activities reported in Nigerian traditional lecture method science class**[**6]. Collaborative leaning therefore promotes students higher-order thinking, improved learning and skills development.

For the purpose of triangulation, the researchers also investigated collaborative learning activities through students' focus group interviews. The interview transcript shows that most of the students have positive responses on improved learning and skills development through; setting their learning goals and working together as a team to achieve their common goals. The students also under go sharing of knowledge by teaching one another and assessing their learning and that of their peers. Teachers' assess individual students and group achievements, providing students with content knowledge and development of their prior knowledge through facilitation process. Evidences from students' interview responses are shown in Table 4.

Table 4. Students' interview responses on improved learningandskilldevelopment

	Example of students responses on improved learning skills development
Team work skills	"I learnt how to collaborate with peers to achieve common goal" AMCS202. "We worked together as a team to address the problem"AMCS204. "I participated in the group learning to solve the problem"AMCS105. "It is important to consider my colleagues' ideas during discussions" AMCS301 "I…tolerate and accept ideas from group peers". AMCS304. **"**Team working improves my learning. I learn better when in a group"AMCS101
Communications skills	"I learned to be socialize and communicate better through presentations" AMCS304. "We need to communicate among selves to get the FILA chart done" AMCS301. "Speaking ability developed as we are presenting our findings" AMCS201. "Now I think I have improved and able to do presentations without fear". AMCS204. "I am able to present to my friends confidently without fear" AMCS105. "I feel so happy about this**".** With better communication, I learn much more"AMCS303.
Higher-order thinking skills	"I learned to think creatively to solve the problem during learning process AMCS301. It is really hard to learn through the approach of PBL." AMCS204. "I developed the ability to look at things in different ways and learn better" AMCS303. "Brainstorming on issues presented in the problem made me think logically "AMCS104. "The idea of questioning the reasons behind actions is interesting"AMCS201. "Sharing knowledge is very common when working with the PBL group" AMCS304.

Finding of this research shows that collaborative learning approach encourage students to set their learning goals and worked together in small groups to achieve the common goals. Students shared knowledge and assess self & peer. Teachers' also assess individual students / group achievements, providing students with content knowledge and development of their prior knowledge through facilitation. The finding is similar to earlier research report that collaborative activities motivates learners to be practically engaged in the learning process through interactions in groups and places the responsibility of learning on the learners, it encourage students to set their learning goals, actively work together to accomplish common goal, share ideas and experiences by teaching one another, freely ask questions and evaluate their learning outcome under teacher's guide[22].Finding of this research revealed that collaborative learning of the PBL increases the frequency of student learning activities from 24 activities per hour [23] to 35 activities per hour in Nigeria Secondary Schools chemistry lessons. The increase in students' participation in the learning process promotes learning and skills development. The finding is supported by a research report that collaborative learning activities generate high frequency of students' interactions which adequately promote higher-order thinking, development of problem solving skills and improved learning [5,6].

The result of this research also revealed that collaborative learning promotes students higher-order thinking activities (69.28%). This is similar to (69.00%) higher-order thinking activities from developed countries [22]. It also reduced the low-order thinking activities from (82.00 %)[6]to(30.71%) in Nigerian Schools PBL module learning process. The result is similar to reports that higher-order thinking skills comprises of complex skills such as problem solving and critical thinking skills generated from the effective collaborative learning activities and high students' interactions in learning process[23]. Finding of this research also shows that collaborative learning activities developed students higher-order thinking skills, improved learning and other problem solving skills including; teamwork and communication skills. The finding is also in accordance with the report that the goals of problem-based learning is to encourage students' development of extensive knowledge and effective problem solving skills through collaborative and self-directed learning [21].

5.0. Implication of the study and conclusion

Collaborative learning approach encourages students to set their learning goals and worked in groups to achieve common goals. The students share knowledge by teaching each other, assess themselves and peer. The teachers evaluate individual &student groups' achievements; they provide students with content knowledge and build on their prior knowledge during facilitation. These collaborative activities generate high frequency of students' interactions which developed students' higher-order thinking skills, improved learning and other problem solving skills. Hence, chemistry teachers should encourage students' interactions and collaborative learning in chemistry classrooms. The researchers recommended for the implementation of collaborative learning approach in teaching and learning chemistry in Nigerian Secondary Schools and higher learning institutions.

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