



PARTICIPATORY TEACHING AND LEARNING APPROACH: A FRAMEWORK FOR TEACHING REDOX REACTIONS AT HIGH SCHOOL LEVEL

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ABSTRACT

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Task.

This study aimed at designing a framework to help students develop a conceptual understanding of redox reactions, which draws on constructivist learning theory. This framework was in the form of participatory teaching and learning approach comprising Insight, Interaction, Task, and Forum. The framework was designed and developed based on the literature and used in a teaching trial. At the prototype phase of the design-based approach, a mixed methods design was employed in data collection. Fifteen students from a second-year senior high school class responded to the achievement test and interacted with the researchers. A stratified sampling procedure was used to select the students. In lessons on redox reactions, the framework helped the teacher to identify students' alternative conceptions and confronted them through cognitive engagements leading to conceptual understanding in redox reactions. Percentages, related samples t-test, and themes were used to analyse data. The results showed that there was an improvement in students' conceptual understanding of redox reactions. It is, therefore, recommended that chemistry educators and researchers should use the framework in large scale research to assure the scientific community the efficacy of it in developing conceptual change in students.

Contribution/Originality: The study contributes to the existing literature by the design and development of an alternative framework for participatory instruction, which is all encompassing in approach. Unlike other instructions, the framework; Insight, Interaction, Task, and Forum, takes advantage of alternative conceptions and ends with students' ability to evaluate colleague's presentations.

1. INTRODUCTION

Concepts in electrochemistry (such as oxidation-reduction reactions) are considered to be challenging to high school students with associate alternative conceptions (Osterlund and Ekborg, 2009; Adu-Gyamfi *et al.*, 2015; Bong and Lee, 2016; Adu-Gyamfi and Ampiah, 2019a;2019b). Students labelled the cathode of an electrolytic cell as the positive terminal and the anode, as the negative terminal, which is considered as an alternative conception. This was an alternative conception because students have explained oxidation occurs at the anode and the reduction, at the cathode, something they picked from text books with no conceptual understanding (Bong and Lee, 2016). Regarding balancing redox reactions, students' alternative conceptions are associated with the introduction of H₂O, OH⁻, and H⁺. For instance, students have explained balancing of redox reactions in acidic medium as H⁺ ions being introduced just because the reaction occurs in the acidic medium (Adu-Gyamfi *et al.*, 2015). Students have

demonstrated conceptual misunderstanding in applying the concept of redox reactions to the production of iron in blast furnace in the form of “the carbon as a catalyst reduces Fe_3O_4 by removing its oxygen” (Adu-Gyamfi and Ampiah, 2019b) and that, oxidation half causes decrease in oxidation numbers of species involved (Adu-Gyamfi and Ampiah, 2019a). In understanding redox reactions, students’ conception of oxidising agents was varied and divergent from the scientific conception (Osterlund and Ekborg, 2009).

Bong and Lee (2016) agreed to the fact that students’ alternative conceptions in electrochemistry (and in this case, redox reactions) have not received the needed attention and redress. Hence, this study was a response to the call to design and develop an instructional strategy (framework) that could help students overcome their alternative conceptions in redox reaction, leading to development competencies of conceptual understanding (Gal *et al.*, 2018) of redox reactions. The research question that guided the study was: “Drawing on the research literature what techniques and strategies can be used to promote students’ conceptual understanding of redox reactions?”

Adu-Gyamfi *et al.* (2015) added their voice to the call to design instructional strategies for addressing students’ alternative conceptions in redox reactions, which would not just be a perceived educational revolution (Gal *et al.*, 2018) but a reality. This framework for teaching and learning of redox reactions was a participatory teaching and learning approach drawing on the constructivist learning theory. This is because several constructivist learning theories advocate the identification of students’ alternative conceptions prior to design and development of instruction that could help to confront the alternative conceptions. When teachers and researchers design appropriate instructional framework, students develop scientific conceptions instead of alternative conceptions. Hence, alternative conceptions need to be considered in any instruction (Calik *et al.*, 2006) which does not make students produce knowledge mechanically (Ciobanu, 2018).

1.1. Participatory Learning

Pain *et al.* (2011) defined a participatory approach as “a set of principles and practices for originating, designing, conducting, analysing, and acting on a piece of research.” The study of Liu *et al.* (2013) revealed that a number of learning strategies evolved in teaching a concept through participatory approach. They identified strategies such as completion, confirmation, repetition, recall, inquiry, and extension. The two descriptions of participatory approach could imply that the approach has no particular methods that should be adopted for a research work or instruction but methods are selected as and when the need arises (Pain *et al.*, 2011) and those methods should reflect the learning needs of students (Kucharcikova and Tokarcikova, 2016).

In research works involving a participatory approach, the participants are involved in planning, action, and reflection of the day’s activities, and evaluation (Pain *et al.*, 2011). Su *et al.* (2010) noted that participatory approach is repetitive and based upon formative evaluation process. It makes use of groups and teams during instruction (Landcare Research, 2002; Ciobanu, 2018). The team for instructing a concept in an academic institution usually consists of teachers, designers, and researchers. All team members are involved in the entire process of instructional design (Su *et al.*, 2010) and it creates a sense of ownership amongst the participants (Andriessen, 2006).

Participatory learning makes use of tasks (Landcare Research, 2002; Ciobanu, 2018) which are defined as the day’s problem(s) and processes which are the way(s) people work together in solving the problem and the instruction is an evolving one which cannot be considered as a single event and takes time as a process. This is to say that participatory instruction is a complex process and no single approach could be sufficient to execute it (Landcare Research, 2002). This complex process is accompanied with formative assessment where “formative assessment is not simply a cognitive process for eliciting understanding, but rather a fundamentally relational act in which teacher and students can participate, construct, and coordinate classroom processes” (Trauth-Nare and Buck, 2011).

According to Trauth-Nare and Buck (2011) participatory approach is practical and collaborative, reflective in process, and purposefully in bridging the gap between theory and practice in a classroom. Reflection is an important

feature of the participatory approach (Pain *et al.*, 2011; Trauth-Nare and Buck, 2011; Kucharcikova and Tokarcikova, 2016). After each engagement using the participatory approach, there should be at least fifteen minutes roundup (reflection) which has the potential of slowing down instruction but it is important to help get to the target (Pain *et al.*, 2011).

Participatory learning is not like seeking an expert view but it is an evolving process that makes use of more than one instructional approach (Landcare Research, 2002). This makes the participatory approach characteristically collaborative (Foster *et al.*, 2008; Su *et al.*, 2010; Trauth-Nare and Buck, 2011; Ciobanu, 2018). Su *et al.* (2010) stated that the participatory approach to learning considers knowledge by doing. It requires that designers of instruction which is participatory should involve the end users in designing rather than designing it for them to use. That is, users are partners and their knowledge is valued in the design process. Participatory approach considers the views of all participants and is collaborative and not left at the door steps of only the developers to plan and develop the instruction (Foster *et al.*, 2008).

In participatory approach, the role of a facilitator is one of importance; and to make the approach collaborative enough, the role of a facilitator should be rotated. However, the facilitator's role should be moderated in such way that the facilitator will not dominate group meetings when he/she is of some expertise in the area being discussed. In the participatory approach everybody within the group should be given the opportunity to make contributions (Pain *et al.*, 2011) and there is the need for a continuous follow-up to ensure that the participants are well informed for effective participatory approach.

Participatory approach is collaborative in learning as students create and solve problems as well as evaluate and settle disputes with respect to colleagues' solutions (Shen *et al.*, 2004). Disputes are important aspect of participatory teaching and learning processes. In that, students are given the opportunity to read their colleagues solutions to problems and therefore could argue on the correctness of some solutions. Shen *et al.* (2004) therefore emphasized that teachers should carefully review students' solutions presented to the class ahead of scoring to avoid disputes. UNESCO (2001) explained that group discussion is a useful participatory instructional tool as through group discussion students learn to agree, disagree, and have mutual respect for the views of other students in a more relax manner (Ciobanu, 2018).

According to McLoughlin and Lee (2007) in participatory learning "learners are active participants or co-producers rather than passive consumers of content, and so learning is a participatory, social process supporting personal life goals and needs." From Shen *et al.* (2004) participatory learning approach engages "students as active participants in the full life cycle of homework, projects, and examination." From the two definitions, it could be seen that students are basically active learners in participatory learning environment (Kucharcikova and Tokarcikova, 2016; Ciobanu, 2018). This is partly because students have opportunity to negotiate for the objectives, knowledge, skills, attitudes, or the teaching and learning methods of a lesson and that every student in a class has a peculiar learning style where teaching should be organised in such a way to engage him or her actively in the teaching and learning process (UNESCO, 2001). This, students in another study perceived, places huge burden on their shoulders (Gal *et al.*, 2018).

Participatory instruction takes advantage of the students' existing experiences (Omollo *et al.*, 2017) and encourages students to share their respective experiences with other students (UNESCO, 2001). Landcare Research (2002) found that since individual as well as group experiences the world in different ways, it is important to involve people on a subject or topic in order to share their respective experiences, activities, and understanding on the subject or topic (Liu *et al.*, 2013).

Liu *et al.* (2013) stated that many educators are calling for the teaching and learning process that is participatory oriented as it offers students more opportunities than just consuming knowledge given by teachers or textbooks. Shen *et al.* (2004) stated that participatory lessons offer students lots of opportunities such as the opportunity to design questions or projects, execute them, and then assess and grade their peers' solution; to read

the solutions of their peers which creates platform for learning from their peers; and to increase their learning in a subject or course material. In addition, participant reactions in the participatory environment create avenues for personal learning; and apart from the possibility of creating personal learning avenues, new ideas evolve for improvement of instruction.

The number of approaches used in participatory approach have always resulted in an increased level of satisfaction. Shen *et al.* (2004) concluded their work by saying the student-centered nature of participatory approach enables students to appreciate and develop interest (Gal *et al.*, 2018) in topical issues in class. Chuen *et al.* (2008) added that success is collaborative which is achieved through the contribution of each student from the groups in a collaborative lesson. UNESCO (2001) emphasized that students achieve more and become more satisfied when they are actively involved in the teaching and learning process; and that students' active participation in lessons is an effective part of their learning of concepts (McLoughlin and Lee, 2007; Liu *et al.*, 2013). The opportunities given to students such as disputing solutions and reading or observing colleagues' solutions in a participatory lesson provide them with opportunities to view subjects or course from more than one perspective of importance (Shen *et al.*, 2004).

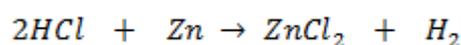
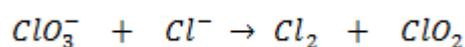
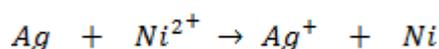
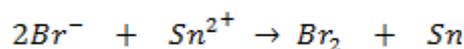
There was, therefore, the need to design and develop a kind of participatory approach that is all encompassing for instruction on redox reactions, in addition to the use of questionnaires, interviews, or observation checklists to explore the presence or otherwise of participatory approaches in teaching.

2. RESEARCH METHODS

This paper is a part of a project on improving students' conceptual understanding on redox reactions. The approach for the project was a design-based research. After the needs assessment stage of the design-based research, there was the need to design and develop an instructional approach to help students learn redox reactions. An embedded mixed methods design was used at this stage of the project to collect both qualitative and quantitative data for the study. Qualitatively, the intervention was designed and developed from literature, used in teaching try-outs where both quantitative and qualitative data were collected, and finally, the qualitative data was used to explain the quantitative data to ascertain whether the intervention could serve its intended purpose.

During the teaching try-out, one school from the study zone was randomly selected for the study. An SHS 2 class from the school participated in the study. The total number of students in the school was 122. The 122 students were stratified into high and low achieving students based on class performance records and the advice of the class chemistry teacher. From the high achieving students, five students were simple randomly selected into five groups and from the low achieving students, ten students were simple randomly selected into the already formed five groups. The simple random sampling procedure helped to ensure that the male and female students had equal chances of being selected. In all, there were fifteen students consisting of nine male and six female students.

In the teaching try-out, a test of ten items was first given to help identify students' alternative conceptions. The test items were constructed based on:



Each item scored two marks; one mark for the selection of the right option and the other mark for demonstration of correct conceptual knowledge. After the teaching try-out, the same test with a different arrangement was given. This helped to compare students' conception before and after the teaching try-out. The data from the test was analysed using percentages, related samples t-test, and themes. Though the sample size was low the randomisation permitted the use of related samples t-test.

2.1. A Four-Stage Participatory Framework

The research question sought to establish techniques and strategies that can be used to improve students' conceptual understanding of oxidation-reduction (redox) reactions based on the research literature. In order to establish the strategy, literature on teaching and learning relating to redox reactions were reviewed. The framework, participatory teaching and learning approach (PTLA) was such an instructional strategy. The framework offered students more opportunities to learn than just taking in knowledge from the teacher. The instructional framework followed the pattern illustrated in Figure 1.

The instructional framework was designed for the purposes of identifying and addressing students' alternative conceptions in learning redox reactions; presenting the concept of redox reactions in a way that offered students maximum interactions in learning chemistry; and improving students' conceptual understanding of redox reactions. The use of the sequence became necessary as there was no single instructional strategy appropriate for the PTLA, which was a complex process (Landcare Research, 2002). The PTLA followed the pattern:

Insight→Interaction→Task→Forum.

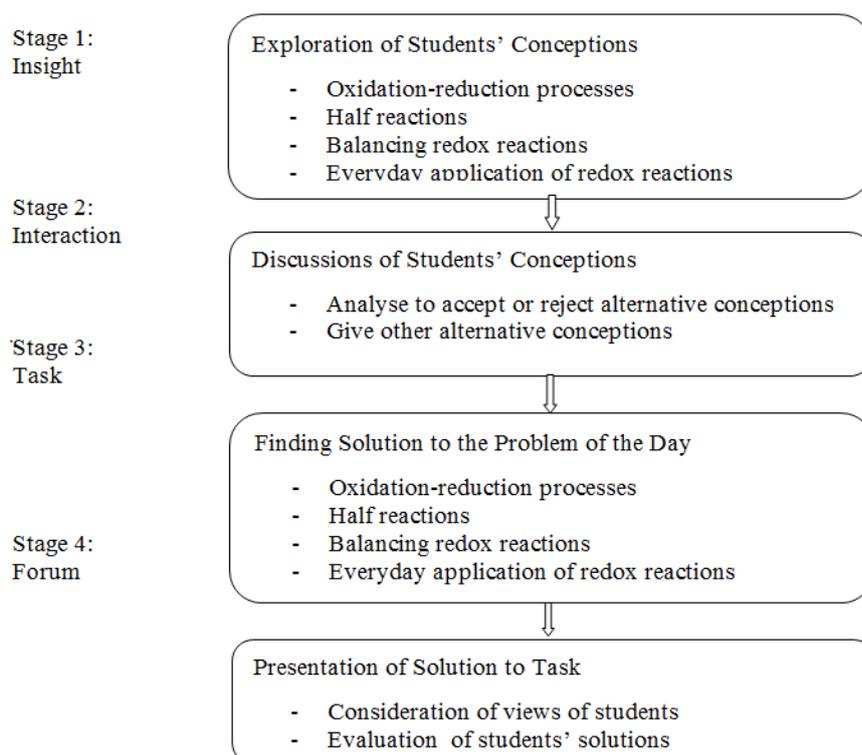


Figure-1. General instructional sequence for oxidation-reduction reaction.

Stage 1 (Insight): Exploration of Students' Conceptions

Insight was the initial stage of the PTLA. It was designed to deduce students' conceptions in the various aspects of redox reactions. This was because students came to classroom with previous knowledge and experiences (Omollo *et al.*, 2017) in redox reactions, which differed from scientifically accepted ones (Sjoberg, 2007). Students were given test items on the various aspects of redox reactions to respond to in writing. They were expected to

respond to the given test using their previous experiences and knowledge. The deduction of students' conceptions was important to the study as it was reported that teachers must first identify students' alternative conceptions to a concept to be able to deploy the appropriate strategy to help students overcome such alternative conceptions (Kruse, 2009; Ernest, 2010).

The aspects considered were oxidation-reduction processes, half reactions, balancing of redox reactions, and everyday application of oxidation-reduction reactions. This means there was more than one lesson where the Insight strategy was used. In one lesson, students' conception of oxidation-reduction processes was deduced and in another, students' conceptions of half reactions; follow by students' conceptions of balancing oxidation-reduction reactions; and students' conceptions of everyday application of oxidation-reduction reactions was deduced (see Appendix). Students' conceptions were categorised as "correct conception" and "alternative conceptions" in each lesson for the Interaction stage.

Stage 2 (Interaction): Discussion of Students' Conceptions

Interaction was the stage where students shared ideas on students' conceptions categorised as correct and alternative conceptions for acceptance or rejection. The Interaction was a key stage in the PTLA because (Wilson, 2010) reported that the process where students make meaning of material is an active process (Kucharcikova and Tokarcikova, 2016; Ciobanu, 2018; Gal *et al.*, 2018) achieved through experiences and interactions with redox reactions. At this stage, student-teacher interactions on the correct and alternative conceptions followed student-student interactions. These two forms of interactions provided students the opportunities to develop correct conceptual understanding on redox reactions.

The Interaction strategy was used partly because knowledge is supposed to be constructed by the individual student but not transmitted (Landcare Research, 2002). Such knowledge construction could be achieved individually or socially (Hein, 1991; Sjoberg, 2007; Lowenthal and Muth, 2008). Students' meaning making through social interactions is being placed ahead of any constructivist instruction (Brown, 2005) hence the adoption of student-student and student-teacher interactions (see Appendix). The Interaction stage was also appropriate for the PTLA as students incorporated their experiences and views to construct knowledge (Tetzlaff, 2009) and that students made meaning of redox reactions through their collaboration (Ciobanu, 2018) negotiation, and involvement in authentic communities of practices (Ernest, 2010; Wilson, 2010).

Student-teacher interactions were used because the PTLA hinged on constructivist instructional approaches, which were student-centred and teacher-facilitated. The student-teacher interaction was important to the Interaction stage as studies have revealed that at the zone of proximal development, students make meaning of redox reactions with support from the teacher who was knowledgeable and experienced in the concept (Kruse, 2009; Ernest, 2010; Taber, 2011). At the zone of proximal development in learning redox reactions, students needed to be monitored and directed (Taber, 2011). The involvement of the teacher considered to be knowledgeable and experienced in redox reactions helped students maximise time in making meaning of the concept (Tetzlaff, 2009). However, teacher guidance in learning redox reactions was minimal at this stage (Taber, 2011).

A single lesson comprised the Insight and the Interaction strategies. The lessons under the Insight and Interaction lasted ninety minutes each (see Appendix). Within the ninety minutes, students first worked individually, followed by work in groups, and finally had a whole class interaction with the teacher. The individual work offered the teacher the opportunity to deduce individual student's conception of redox reactions; the group work offered the teacher the opportunity to appreciate which student conceptions were accepted or not accepted by students; and the interactions with the teacher helped the teacher to correct students' conceptual understanding of redox reactions.

Stage 3 (Task): Finding Solution to the Problem of the Day

At the third stage of the PTLA, the teacher, first, guided students to review previous lessons on the redox reactions. Students then solved the task (the problem of the day) (Ciobanu, 2018) which was not only an attribute of constructivist instruction (Wilson, 2010) but a strategy used in participatory learning (Landcare Research, 2002). The problem of the day was given on a worksheet and students responded to the problem in groups. The group interactions was an attempt to find solution to the problem (UNESCO, 2001) provided students with an opportunity to share ideas in solving the problem of the day. The group interactions also provided students cooperativeness in problem solving (Ernest, 2010).

Students found the solution to any given problem as a process. That is students teamed up in the groups in solving the given problem (Landcare Research, 2002). Time was an important factor in the process as a long period of time was needed by the students to make meaning of the concept of redox reactions (Hein, 1991; Tetzlaff, 2009; Taber, 2011). Hence, students were given thirty minutes to look for the solution to any given problem of the day.

Students were provided with instructions, which ensured orderliness in the groups, as they interacted to solve the problem of the day. The instruction spelt out rules for the group work were: 1) respect each other's views; 2) talk only when it is your turn; 3) guide against unnecessary arguments; and 4) write only points agreed upon by group members. This ensured that none of the group members dominated or imposed their respective views on others but shared ideas, agreed or disagreed to come out with the solution to the problem of the day (Appendix).

Stage 4 (Forum): Presentation of Solution to Task

The Forum was the stage where students presented solutions and judged (Ciobanu, 2018) the most appropriate solution to the task given. One student from each group presented the solution to the problem of the day and explained the solution to the class as well. Students could raise issues about the solutions presented. The Forum afforded a two-way communication system where students shared ideas as a class and with the teacher (Trauth-Nare and Buck, 2011; Ciobanu, 2018). This offered students opportunity to expand and modify their ideas (Cooperstein and Kocevar-Weidinger, 2004; Tetzlaff, 2009) on redox reactions.

Regarding the two-way communication, students were allowed to challenge solutions presented by the group members on a given task (Richardson, 2003; Ciobanu, 2018) on redox reactions. This, in some instances, generated a contest of ideas among students. These contentions of ideas were not directly settled by the teacher. Students settled any disagreement as they attempted to argue on the correctness of solutions presented on a given task (Shen *et al.*, 2004) and in an attempt learnt from each and another. Students having finished settling the disputes and judging the most appropriate solution to the problem, the teacher stressed the correctness of the concepts appropriate for solving the day's problem. This contributed to students' conceptual development on the concept of redox reactions.

A unit lesson on redox reactions comprise the Task and the Forum (see Appendix). Hence, there were individual lessons after those on the Insight and Interaction stages which comprised the Task and the Forum stages. Lessons under the Task and the Forum took 90 minutes.

3. STUDENT PERFORMANCE ON REDOX REACTIONS

The research question further sought to establish whether the instructional approach could help promote students' conceptual understanding on redox reactions. This was achieved during the teaching try-out stage of the design-based research approach. A pre-test and post-test in redox reactions were administered during the teaching try-out to students. The results of students' percentage score of each item in the pre-test and post-test are presented in Figure 2.

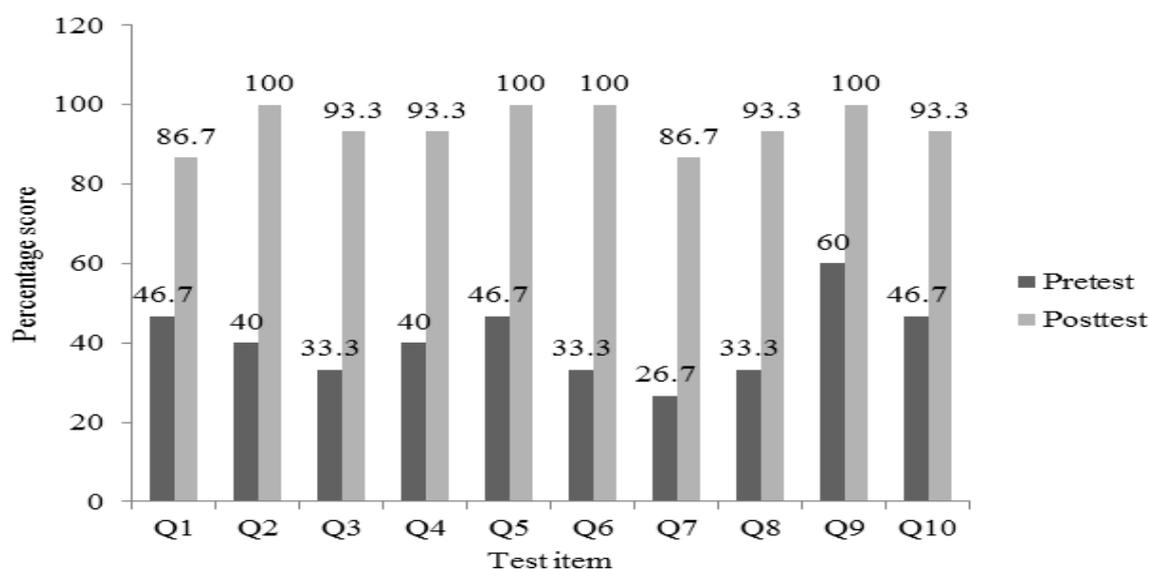


Figure-2. Bar graph of student percentage score of each item in the pre-test and post-test on oxidation-reduction reactions.
Source: Field data (2018).

The results from Figure 2 show that students failed to score full marks on all the items on redox reactions in the pre-test. The best was Item 9 where 60.0% of the students scored the full mark and the rest of the items had less than 50.0% of the students scoring them. The students, therefore, had difficulty in redox reactions. However, in the post-test, an overwhelming majority of the students scored most of the items on oxidation-reduction reactions. In some instance, all students scored the item and the least percentage of students scoring an item in the post-test was 86.7%. This implies that teaching redox reactions with PTLA helped the students to conceptualise the concept better and hence, the improvement in students' percentage score in the post-test.

Students' mean scores in the pre-test and the post-test were also calculated. The results are presented in Table 1. The mean score of the students in the pre-test was 5.7 (SD = 3.8) with a minimum score of 0 and a maximum score of 11 out of the total score of 20. Two-thirds of the students scored marks ranging from 1.9 to 9.5 out of 20 marks. Students' performance in the pre-test was therefore poor.

The results in Table 1 also show that the mean score of the students in the post-test was 17.1 (SD = 1.5) with a minimum of 15 marks and a maximum of 19 marks out of a total score of 20 marks. Two-thirds of students' scores ranges between 15.6 and 18.6 out of total score of 20 marks. The results clearly show a marked improvement in students' performance. This could be attributed to students' experiences with PTLA in learning oxidation-reduction reactions which has helped them to improve on their performance.

Table-1. Results of related samples t-test analysis.

Test	N	Mean	SD	t	Df	p
Pre-test	15	5.7	3.8	16.9	14	0.001*
Post-test	15	17.1	1.5			

* Significant, $p < 0.05$.

Source: Field data (2018).

The results from Table 1 further show that there was a statistical significant difference between the students' performance in the pre-test and post-test with a mean = 17.1 (SD = 1.5) compared to their performance on redox reactions at the beginning of teaching and learning of the concept using PTLA (mean = 5.7, SD = 3.8, $t(14) = 16.9$, $p = 0.001$). The size of the difference in the mean scores was found to be very strong (effect size = 0.976).

To further establish the relationship between students' performance in the post-test and those of the pre-test, the Pearson correlation coefficient was conducted and analysed.

Table-2. Conceptual change in students' learning of redox caused by PTLA.

Theme	Conceptual change	
	Pre-test (alternative conception)	Post-test (conceptual knowledge)
Identification of redox reactions	<p>Zn^{2+} has been oxidised by gain of electrons to form Zn (PR011)</p> <p>$Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$ because the presence of the Cu makes the equation redox from the others (PR005)</p>	<p>the answer is $Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$ because the oxidation number of Zn is 0 and Cu is +2 at the reactant side but in the product Zn is +2 and Cu is 0 (PO011)</p> <p>the answer is $Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$ because there are both oxidation half and reduction half reactions (PO005)</p>
Oxidised specie	<p>Br^- because it has gained an electron (PR003)</p> <p>Br^- there is an increase in charge from $2Br^-$ to Br_2 (PR007)</p>	<p>Br^- has increased in oxidation number from -1 to 0 (PO003)</p> <p>Br^- because it increased in oxidation number (PO007)</p>
Reduced specie	<p>Sn^{2+}; because it carries out electrons which loss some charge (PR010)</p> <p>Br^-; because it changes from its pure state to form a molecule (PR002)</p>	<p>Sn^{2+}; because the oxidation number reduced or changed from +2 to 0 (PO010)</p> <p>Sn^{2+}; has reduced in oxidation number from +2 to 0 in the reaction (PO002)</p>
Oxidising agent	<p>Ni^{2+}; because its net charge has been reduced from Ni^{2+} to Ni (PR003)</p> <p>Ni^{2+}; causes the Ag to increase in charge thus, oxidised. That is Ni^{2+} is reduced so it is the oxidising agent (PR007)</p>	<p>Ni^{2+}; has caused Ag to increase in oxidation number from 0 to +1 (PO003)</p> <p>Ni^{2+}; because it caused the oxidation number of Ag to increase from 0 to +1 (PO007)</p>
Reducing agent	<p>Ni^{2+}; because it changes from ionic state to its atomic state (PR002)</p> <p>Ni^{2+} is reducing agent because it reduced to Ni (PR006)</p>	<p>Ag has caused Ni^{2+} to decrease in oxidation number (PO002)</p> <p>because Ag has caused a decreased in oxidation number of Ni^{2+} (PO006)</p>
Oxidation half	<p>$ClO_3^- \rightarrow ClO_2$; because it changes from ionic state to a compound (PR002)</p>	<p>$Cl^- \rightarrow Cl_2$ is the oxidation half because Cl^- has increased in oxidation</p>

	the charge on Zn has been oxidized to give Zn^{2+} and due to increase in charge of Zn^{2+} (PR013)	number to form Cl_2 " (PO002). Zn increased in oxidation number from 0 to +2 (PO013)
Reduction half	$Cl^- \rightarrow Cl_2$; because the number of chlorine in the reaction has been reduced" (PR009) because Cl^- loses the extra electron to become Cl_2 (PR011)	ClO_3^- reduces in oxidation number (PO009) the reduction half is $ClO_3^- \rightarrow ClO_2$ because Cl changed from +5 to +4 (PO011)

Source: Field data (2018).

The results from the Pearson correlation coefficient showed that a very strong and positive correlation was found between students' performance in the pre-test on redox reactions and their performance in post-test on redox reactions ($r = 0.9$, $p = 0.001$). This is an indication that the students' performance in the pre-test and post-test in the sample of students shared 81.0% of their variance in common. The findings on the students' mean performance showed that there was improvement, which could be attributed to the impact of the PTLA on student learning of redox reactions.

The research question sought to further establish any conceptual changes experienced by students in learning redox reactions using PTLA. The results are presented in line with identification of redox reaction, oxidised specie, reduced specie, oxidising agent, reducing agent, oxidation half-reaction, and reduction half-reaction. Sample explanations and codes (such as 'PR001' for student 1 in the pre-test and 'PO001' for student 1 in the post-test) are used to support the presentations.

The PTLA was designed and developed from participatory approaches grounded in constructivism. It was a four-stage instructional strategy (consisting of Insight, Interaction, Task, and Forum). The findings showed that students' conceptual understanding of redox reactions improved in the post-test leading to an enhanced performance (Gal *et al.*, 2018). This could be attributed to the students' learning of redox reactions using PTLA, which exposed them to conceptual problems, gave them opportunity to solve problems on their own, and helped them to identify and understand their mistakes (Felder, 1993). This is because not only was the PTLA helping individual students to perform on the test items in redox reactions but they were able to justify correctly, the chemistry behind concepts under redox reactions. Hence, the new teaching approach (involving Insight, Interaction, Task, and Forum stages) was effective in developing students' conceptual understanding on redox reactions. It is therefore recommended that researchers and educators in the area of chemistry education should use the framework for instructing chemical concepts in a life class to ascertain its effectiveness in improving students' conceptual understanding in chemistry.

4. CONCLUSION

The instructional framework designed and developed for this study was a participatory teaching and learning approach, which is student-centered, evaluative, and reflective. It stimulates evaluation and reflection on the part of students with teachers providing little support. These unique features of the PTLA could help in building students' confidence in learning and hence, leading to conceptual understanding of redox reactions. At the Insight stage of the PTLA, student alternative conceptions were deduced and informed teaching. It made use of students' alternative conceptions to help them develop conceptual understanding of chemical concepts. The framework responds to the call by chemistry educators and researchers to find ways of erasing students' alternative conceptions in chemical concepts and enhance conceptual understanding in chemistry. Thus, findings of this study

not only supplement findings in related and relevant studies but also add substantive information to the existing knowledge related to the teaching and learning of redox reactions.

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APPENDIX

Students' Conceptions of Half Reactions

Lesson 1

The aim of the lesson is to find out students' conceptions of oxidation half reactions and reduction half reactions. It will further help to find students' conceptions of oxidised and reduced substances and oxidising and reducing agents in oxidation-reduction reactions. To be able to achieve this, the following activities will be performed.

Insight stage 1: Students will be given Worksheet 1 containing some alternative conceptions on oxidised substance and oxidising agents and reduced substance and reducing agents to identify themselves with. Students will first identify themselves with the statements as individual students in 20 minutes.

Worksheet 1

Instruction: The following are a number of statements relating to oxidised and oxidising agents and reduced and reducing agents. Study them carefully. Indicate whether you accept the statement as correct or you do not accept the statement as correct.

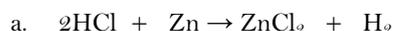
Group Number: **Date:**

1. A substance with positive charge is an oxidising agent.	
2. Oxidising agent is a substance that is oxidised by losing electrons.	
3. Oxidising agent accepts oxygen atoms to change oxidation state.	
4. A substance with oxygen atom in its molecule is oxidised.	
5. An oxidised substance is a substance whose ionic charge increases as it accepts electrons.	
6. Reducing agent is a substance that accepts electrons.	
7. Reducing agent accepts oxygen atoms to change oxidation state.	
8. Reducing agent is a substance that does not have oxygen in its molecule.	
9. A reduced substance is the substance that loses electrons to change its charge.	
10. Explain the meaning of an oxidising agent (if different from any of the above).	
11. Explain the meaning of an oxidised substance (if different from any of the above).	
12. Explain the meaning of reducing agent (if different from any of the above).	
13. Explain the meaning of reduced substance (if different from any of the above).	

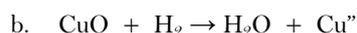
Interaction stage 1: After the 20 minutes, students will form groups of three members each. In the groups, students will discuss among themselves the alternative conceptions and each student's conceptions of oxidising/reducing agents and reduced/oxidised substances. Students will discuss to accept or not to accept such conceptions in 20 minutes.

In the next 10 minutes, the teacher will discuss with students the conception of oxidising/reducing agents and reduced/oxidised substance. The teacher will use sample reactions to bring out the conception of oxidising/reducing agents and reduced/oxidised substances.

Insight stage 2: Students will be engaged in a second activity on conception of half reactions. In this activity, students are expected to deduce the half reactions of some given reactions. The question for the activity will read: "Deduce the a) oxidation half and b) reduction half of the following reactions and give reasons for your answer:



REASON:



REASON:

Students will perform the second activity in 15 minutes. After the 15 minutes, students will receive Worksheet 3 on alternative conceptions of half reactions for the Interaction stage of the second activity.

Worksheet 3

Instruction: The following are a number of statements relating to oxidation half and reduction half. Study them carefully. Indicate whether you **accept** the statement as correct or you **do not accept** the statement as correct.

Interaction stage 2: Students will discuss, in groups, each student's conception of oxidation half and reduction half reactions, in the light of the given alternative conceptions. Students will discuss to accept or not to accept the alternative conceptions of half reactions. The interaction will be 15 minutes.

Thereafter, the teacher will discuss with students the conception of half reactions for the next 10 minutes. The teacher will use further sample reactions to assist students develop conceptual understanding of oxidation half and reduction half reactions.

Group Number: **Date:**

1. Oxidation half involves gain of electrons.	
2. Oxidation half involves gain of electrons to increase in oxidation state of substance.	
3. Reduction half involves loss of electrons.	
4. A positive ion gives an indication of reduction reaction.	
5. Removal of an oxoanion is an indication of reduction half.	
6. Reduction half involves decrease in oxidation state caused by loss of electrons	
7. Reduction half involves decrease in oxidation state as a result of loss of oxygen atoms.	
8. Explain the meaning of oxidation half (if different from any of the above).	
9. Explain the meaning of reduction half (if different from any of the above).	

Lesson 2

The aim of Lesson 2 is to provide students with the opportunity of using the knowledge acquired on half reactions. This will help students to expand and modify their thinking and ideas on half reactions.

Task stage: The teacher will revise previous lesson on half reactions with students. Students will sit in their groups of three members each. Students will receive Worksheet 4 containing the problem of the day. Students will interact among group members to find solution to the problem of the day using the worksheet. The activity will be 30 minutes.

Worksheet 2

Instruction: The following are a number of reactions and you are to use the concept of oxidation number to identify the oxidation half- and reduction half- reactions among them.

- $2\text{KBr} + \text{Cl}_2 \rightarrow 2\text{KCl} + \text{Br}_2$
- $\text{Fe} + 2\text{HCl} \rightarrow \text{FeCl}_2 + \text{H}_2$
- $2\text{KClO}_3 \rightarrow 2\text{KCl} + 3\text{O}_2$
- $\text{Fe}^{2+} + \text{Cr}_2\text{O}_7^{2-} \rightarrow \text{Fe}^{3+} + \text{Cr}^{3+}$

You are to analyse the reactions using the statements in the table below.

Forum stage: After the 30-minute period of an attempt of students looking for solution to the problem of the day, a member from each group will present and explain their solution to the class. Students will raise questions about the solution presented. After all the groups' presentation of the solution, students will judge the most appropriate solution to the problem of the day. The time for the presentations will be 45 minutes.

The teacher will finally stress the most appropriate solution in 15 minutes. Where there is a shortfall in the groups' presentations on half reactions, the teacher will help students identify and modify their thinking and ideas. The teacher will also respond to students' issues on areas that need clarification.

Group Number: Date:

<p>1. Identify the oxidised species and oxidising agent in reaction (1) above using oxidation number. 2. Identify the reduced species and reducing agent in reaction (1) above using oxidation number.</p>	
<p>3. Identify the oxidised species and oxidising agent in reaction (2) above using oxidation number. 4. Identify the reduced species and reducing agent in reaction (2) above using oxidation number.</p>	
<p>5. Identify the oxidised species and oxidising agent in reaction (3) above using oxidation number. 6. Identify the reduced species and reducing agent in reaction (3) above using oxidation number.</p>	
<p>7. Identify the oxidised species and oxidising agent in reaction (4) above using oxidation number. 8. Identify the reduced species and reducing agent in reaction (4) above using oxidation number.</p>	
<p>9. Write down the half reactions and the ionic equation for each of the given reactions.</p>	<p>1.a. oxidation half b. reduction half c ionic equation 2.a. oxidation half b. reduction half c ionic equation 3.a. oxidation half b. reduction half c ionic equation 4.a. oxidation half b. reduction half c. ionic equation</p>
<p>10. Draw your conclusion justifying the concept of half reactions.</p>	

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