FOSTERING STUDENTS' UNDERSTANDING OF LE CHATELIER'S PRINCIPLE USING CORRECTIVE FEEDBACK INSTRUCTIONAL STRATEGY

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ABSTRACT

The paper examined the use of corrective feedback as an instructional strategy to foster understanding of Le Chatelier's principle among secondary school chemistry students. Le Chatelier's principle which focuses on chemical reactants and products in chemical equilibrium confirms that reaction system tends to counteract the effect of any variation in the variables to maintain the equilibrium as in SSS chemistry curriculum. The principle needs to be understood and applied by all chemistry students. It views classroom questioning as a base for effective feedback and correctives and provided a checklist for planning such questions. Inability of chemistry teachers to involve students in classroom discussions, delay feedback and ineffective mode of classroom interaction among learners constitute hindrance to students understanding of Le Chatelier's principle. Application of corrective feedback as a strategy for classroom chemistry instruction to teach Le Chatelier's principle was therefore illustrated. Corrective feedback assisted the students to have deeper understanding of Le Chatelier's principle and also enhanced their participation when discussing this concept in the class as active learners. Chemistry teachers could apply active learning interaction through corrective feedback strategy to improve students' understanding of Le Chatelier's principle. Students' responses to questions should be given immediate feedback to remove conceptual confusion during the course of lesson.

Introduction

Chemistry has derived for itself a central place in the general curriculum of senior secondary school physical sciences. Its curriculum is organized around the major concepts of energy, periodicity and structure. The fundamental principles of chemistry include particulate theory of matter, periodicity, chemical combination, quantitative aspect of chemical reactions, rate of reaction and equilibrium among others. Kolb (1984) described four major processes which are applicable to chemistry learning: Concrete experience - learning through direct involvement in a new experience; reflective observation - learning through watch others; abstract conceptualization - learning by creating concept and theories to describe and explain one's observation; and active experiment - learning by using the theories and concepts that one has derived to solve problems and explain one's observation.

Chemistry teachers also exhibit different teaching styles as experts, formal authorities, personal models, facilitators or delegators. Pedagogical style is teacher-centred in which the teacher decides what is taught and how it is taught. Learner is dependent on the teacher for everything, direction and content. Nicholas, Lightbrown and Spada (2001), for example, found that feedback appear to be most effective in contexts where it is clear to the learner that the recast is a reaction to the accuracy of the form, not the content, of the original utterance (see also Ellis, Basturkmen & Loewen, 2001; Lyster, 2001; Long, Inagaki & Otega, 1998). More general, studies further indicate that the efficacy of corrective feedback in the oral classroom is determined by a number of factors. For instance, Havranek & Cesnik (2001) found that the success of corrective feedback is affected by its format, the type of error, and certain learner characteristics.

Feedback can be said to describe any communication or procedure given to inform a learner of the accuracy of a response (Mory, 1996). As evidenced in the literature, there are many types of feedback that a student could receive from an instructor. The type of feedback that will be studied in this paper is corrective feedback. A working definition of corrective feedback is any comments or suggestions an instructor gives a student (verbally or in writing) on any assignments, quizzes and exams. Corrective feedback does more than simply inform the student whether an answer is correct; it provides the student with specific suggestions on how to improve the answer or gives additional information or resources to help guide the student to the correct answer. In most cases this procedure leads to a better understanding of the course material. Therefore, instructor corrective feedback should not only supply students with information about their performance, but it should provide the student with self-assessment (Looms, 1997). Students need to be given useful and corrective feedback throughout a course (Smith-Gratto, 2003). When the learner characteristics taken into consideration, verbal intelligence, relative proficiency (within levels at school or university), and the learner's attitude towards correction proved to be most influential. Despite a vast interest in studying the role of corrective feedback in the oral classroom, very little research has been conducted especially in applying corrective feedback as a strategy in classroom in teaching of chemical concepts. This paper therefore identified a feedback and correctives instructional strategy to enhance understanding of Le Chatelier's principle.

Questioning as a Foundation for Effective Corrective Feedback

Pedagogical style is teacher-centred in which the teacher decides what is taught and how it is taught. Learner is dependent on the teacher for everything, direction and content. The focus of learning is to build a foundation of knowledge that may be useful later. Whitman and Schwenk (1997) categorized teachers into four: assertive, suggestive, collaborative and facilitative. Assertive teachers gives direction, ask questions and gives information. Suggestive teachers suggests alternatives, offer opinions and relate personal experience while collaborative teachers accepts learners ideas, explore learners ideas relate personal experience. Facilitative teachers consider learners feelings, offer feelings and encourages. Chemistry teachers need to exhibit these characteristics in order to effectively teach chemical concepts that seem to be abstract and difficult.

Questioning is a formidable process in the classroom that has the aim of causing necessary changes in learners. Asking questions is natural and intuitive. Teachers ask questions as soon as the lesson starts and continue until the end. Asking questions forms part of any lesson because it invites the student to think, and even within a 'lecture' style lesson, rhetorical questions are used to invite silent agreement or begin the organisation of ideas to present a response. Teachers use questions to engage the students and sustain an 'active' style to the learning. The teacher also uses questions as part of the assessment of learning in order to determine how they best structure, organise and present new learning. However, research has found that most teachers only wait 0.7seconds for an answer (Ohta, 2000). Developing questioning requires much greater emphasis on the time provided for students to think individually, collaboratively and deeply to develop and share better answers. Historically, teachers have asked questions to check what has been learnt and understood, to help them gauge whether to further review previous learning, increase or decrease the challenge, and assess whether students are ready to move forward and learn new information. This can be structured as a simple 'teacher versus the class' approach, where the teacher asks a question and accepts an answer from a volunteer, or selects/conscripts a student to answer. These approaches are implicit in any pedagogy, but teachers need a range of questioning strategies to address different learning needs and situations.

According to McDoagall and Granby (1997) teachers use questioning as part of their teaching for many reasons, but often to:

(i) maintain the flow of the learning within the lesson;
(ii) engage students with the learning;
(iii) assess what has been learned;
(iv) check that what has been learnt is understood and can be used;
(v) test student memory and comprehension;
(vi) seek the views and opinions of pupils;
(iv) provide an opportunity for pupils to share their opinions/views and seek responses from their peers;
(vii) encourage creative thought and imaginative or innovative thinking;
(viii) foster speculation, hypothesis and idea/opinion forming;
(ix) create a sense of shared learning and avoid the feel of a 'lecture';
(x) challenge the level of thinking and possibly mark a change to a higher order of thinking; and
(xi) model higher order thinking using examples and building on the responses of students.

Some have suggested that recitation-like structures that involve a large proportion of literal questions and corrective feedback enable the teacher to attain a priori instructional goals, maintain high levels of attention, especially when the topics are algorithmic and factual (Stodolsky, Ferguson, & Wimpelberg,1981). But at the same time, Dillon (1983; 1985) suggests that the practice of asking questions to which the answers are already known and the rapid pace at which these are asked can impede movement towards discussion.

A Checklist for Planning Questions for Feedback and Correctives in Teaching Le Chatelier's Principle

Chemistry teachers need to possess required questioning abilities in order to foster greater understanding of the Le Chartelier's Principle. Teachers could ensure effectiveness of such questions by bearing the following in mind:

Knowing as a basis for action

(i) What basic knowledge does the learner need?
(ii) What particular skills does the learner need? (e.g. identifying and balancing of chemical reactions and reaction rates procedures)
(iii) What are the relevant facts? And theories?
(iv) What skills does the learner need to find out for herself or himself?

(v) How does this foster understanding of other chemical concepts? Does the learner have a variety of prerequisite skills and techniques from which to choose?

Demonstrating understanding

(i) Can the learner identify main points? Similarities? Differences?
(ii) Is it possible to ask any of these questions:
(iii) Can you explain in another way?
(iv) Why did this happen?
(v) What were/will be the consequences?
(vi) How does this affect you/other people? Why?
(vii) Would you make the same decision? Why? Why not?

Application of Feedback and Correctives Instructional Strategy

Feedback and corrective instructional strategy is focused on how to handle right and wrong answers during teaching and learning situation. Borich (2010) identified four students' classroom responses:

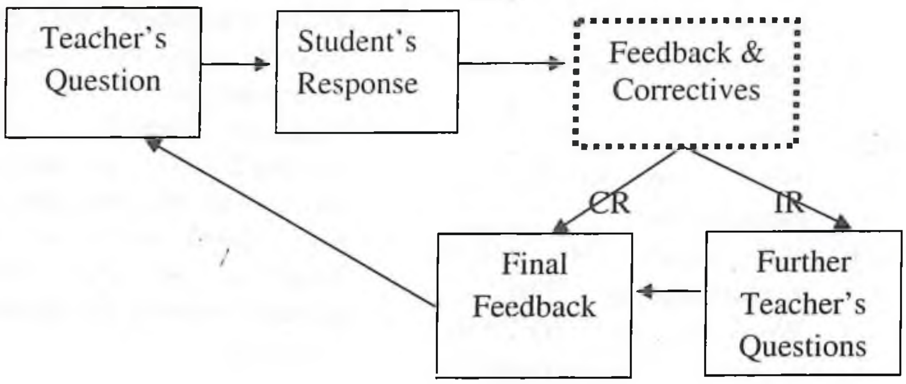
(i) Correct, quick and firm.
(ii) Correct but hesitant
(ii) Incorrect due to carelessness
(iii) Incorrect due to lack of knowledge

Chemistry teachers must strive most of the times to inspire correct, quick and firm responses from students. This comes mostly during the later part of the lesson. Sixty to 80% correct responses are required in a practice and feedback session (Linsdey, 1991). The urgency of providing right answers minimizes irrelevant students' responses and classroom distraction. Correct and hesitant response takes place in a practice and feedback session at the beginning or middle of lesson. Teachers should give positive feedback to encourage such students to reinforce the statement e.g. *"Good or That's correct".* Teachers can also restate the answer, assuring the student that it is correct.

About 20% of student responses fall into incorrect because of carelessness and teachers are tempted to scold, admonish or even verbally punish him e.g. *insensible response, I am ashamed of you, I thought you are brilliant than that etc.* The best response is to acknowledge that the answer is wrong and immediately move to the next student for the correct answer. Other set of student respond incorrectly to teachers' questions for lack of knowledge especially during the initial stage of the lesson or unit. When this happens, teachers must provide hints, probe, or change the question or stimulus to a simpler one. The most common` strategies for incorrect responses are:

(i) Review the key facts or rules needed to produce a correct solution
(ii) Explain the steps used to reach the correct solution
(iii) Prompt to clues or hints that represent partially correct answer
(iv) Use a different but similar problem to guide the students to the correct answer. Reviewing, re-explaining and prompting are effective until approximate by 80% of the students responding correctly.

The feedback and correctives could be represented as shown in Figure 1 below



CR = Corrected Response   IR = Incorrect Response

Figure 1: Diagrammatic Representation of Feedback and Correctives Mode

Linsdey (1992) states that active responding include orally responding to a question, writing out the correct answer, calculating an answer or physically making a response while passive responding include listening to teacher's answer, reading about the correct answer or listening to classmates recite the right answer. Huffman (2005) reported a strong and positive relationship between leaner achievement and active responding. When providing feedback and corrections, chemistry teachers should do the following:

(i) Give direction that focus on the response that learners are expected to make.
(ii) Design instructional materials both for initial learning and practice so that learners can produce correct

answers 60% to 80% of the time.

(iii) Select activities to engage your students in active responding about 75% of the time.

Le Chatelier's principle is an essential aspect of chemical equilibrium which chemistry students should understand and the appropriate teaching styles for such a topic warrant teachers to see themselves as facilitators during classroom chemistry teaching learning process.

Overview of the Le Chatelier's Principle

If a system of chemical reactants and products in stable equilibrium is perturbed by subjecting it to a small variation in one of the variables that desire the equilibrium state, the system will tend to return to an equilibrium state. Le Chatelier (1888) considered these problems theoretically and arrived at the general principle that a thermodynamic system tends to balance or counteract the effect of any imposed stress. The principle indicates that if heat is evolved in a chemical reaction, increasing the temperature tends to reserve the reaction; if the volume decreases in a reaction, increasing pressure shifts the equilibrium position towards the product side. He postulated that equilibrium state relies on

(i) Temperature of the reacting system

(ii) Total pressure of the reacting system for gaseous reaction.

(iii) Concentration of the reacting species in the system.

Change in Temperature

(i) $X+Y \rightleftharpoons Z$ $-\Delta H$ (exothermic)

Increase in temperature shifts equilibrium from right to left

(ii) $X+Y \rightleftharpoons Z$ $-\Delta H$ (exothermic)

Decrease in temperature shifts equilibrium from left to right

(iii) $X+Y \rightleftharpoons Z$ $+\Delta H$ (endothermic)

Increase in temperature shift equilibrium from left to right

(iv) $X+Y \rightleftharpoons Z$ $+\Delta H$ (endothermic)

Decrease in temperature shift equilibrium from right to left

Change in Pressure

For reaction that involves gases, increase or decrease in volume will affect the equilibrium state

(i) $2X_{(g)} + Y_{(g)} \rightleftharpoons 2Z_{(g)}$

Decrease in volume will also decrease the pressure to shift equilibrium to the left

(ii) $2X_{(g)} + Y_{(g)} \rightleftharpoons Z_{(g)}$

Volume decrease with increase in pressure shifts equilibrium to the right.

(iii) $X_{(g)} + Y_{(g)} \rightleftharpoons 3Z_{(g)}$

Volume increase with decrease in pressure shifts equilibrium to the right.

(iv) $X_{(g)} + Y_{(g)} \quad\quad 3Z_{(g)}$

Volume decrease with increase in pressure shifts equilibrium to the left

(v) $X_{(g)} + Y_{(g)} \quad\quad 2Z_{(g)}$

If there is no change in volume, there would be no increase or decrease in pressure, therefore, there would also be no observable shift in the position of the equilibrium (Ababio, 2005).

Change in Concentration

$W + X \rightleftharpoons Y + Z$

W and X are reactants while Y and Z are products. At equilibrium, there exists a definite concentration W, X, Y and Z. Increase in concentration of W will disturb the equilibrium, and thereby shift to counteract the increase. X will react more with W to produce more of Y and Z. Therefore, the equilibrium with shift to right favouring forward reaction. Also, if Y or Z is continually removed, the equilibrium will shift to the right.

Linking Feedback and Correctives Strategy to the Teaching of Le-Chatelier's Principle

Topic: Le Chatelier's Principle
Class: SSS 2
Duration: 80 minutes
Specific Objectives: At the end of the lesson, students should be able to

(i) list three factors on which the equilibrium state depends
(ii) state Le Chateliers principle
(iii) identify changes in conditions of equilibrium reactions
(iv) explain the directions of shift in equilibrium position if any of the conditions is altered.

Teaching Method: Classroom Discussion using Feedback and Corrective Strategy

Presentation:

Step 1: Teacher reviews previous lessons by asking the following questions:

Teacher: A reaction which occurs in both forward and backward directions is called _______. Ngozi.
Ngozi: Chemical reaction.
Teacher: No, Wale, can you answer the question?
Wale: Reversible reaction.
Teacher: Correct. That is a brilliant answer.

(a) **Teacher:** The $\rightleftharpoons$ represented in the reaction $A + B \rightleftharpoons C + D$ symbolises ____________. Adamu

Adamu: Forward and backward (equilibrium/reversible) reaction

Teacher: Right answer.

(b) **Teacher:** Kingsley, come out to write the equilibrium constant relationship for this reaction

$$aD + bF \rightleftharpoons cG + eH$$

Kingsley (*comes out reluctantly to write):*

$$K = \frac{cG + eH}{aD + bF}$$ (*incorrect for lack of knowledge)*

Teacher: That is not correct. Hauwa, come out to try

Hauwa: *(writes on the board):*

$$K = \frac{[G]^c\ [H]^c}{[D]^a b[F]}$$ *(incorrect because of carelessness)*

Teacher: Wrong. Hauwa, check your answer, there is something wrong somewhere.

Hauwa: $$K = \frac{[G]^c\ [H]^c}{[D]^a [F]^b}$$ *(corrected herself)*

Teacher: That is correct.
Step 2: Teacher states the topic of the day with the objectives of the lesson.
Step 3: Teacher leads the students to state and explain the three conditions on which equilibrium state is dependent.

Teacher: Mention 6 factors that affect the rate of chemical reaction. Joy, mention two.

Joy: Nature of reactant and concentration (correct, quick and firm response)
Teacher: Correct. Samuel, give another two.
Samuel: Light and heat (*incorrect for carelessness*)
Teacher: Incorrect, Abdullahi, correct him.
Abdullahi: Light and temperature

Teacher: Good. Akin, mention the last two.
Akin: Catalyst and surface area of reactant
Teacher: Correct.
Teacher then reinstates that the three factors for equilibrium state are:

(v) Temperature of the reacting system.
(vi) Total pressure for reaction involving gases.
(vii) Concentration of the reacting substances

Step 4: Teacher gives specific examples to illustrate how these factors affect the equilibrium.
Example 1: Consider the equilibrium reaction represented.

Teacher *(writes on board):* $X_2 + 3Y_2 \rightleftharpoons 2XY_3$: ΔH-ve. What happens to the equilibrium if the temperature at the equilibrium is increased?

Teacher: What does ΔH = -ve mean? Dele

Dele: It means that heat is released in the system.

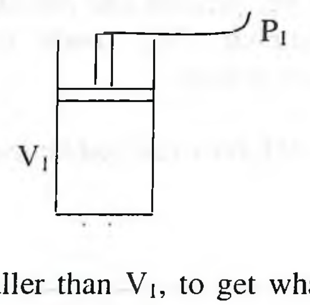
Teacher: Good. What do we call this phenomenon? Adamu.
Adamu: Exothermic (*hesitant*)
Teacher: You are right. What happens to the equilibrium if the temperature at equilibrium is increased? Chinyere.
Chinyere: The equilibrium shifts to the right.
Teacher: No, that is not correct. Sade, can you help her?
Sade: The reaction moves forward.
Teacher: Wrong. Sade, you know that heat is given off during the reaction, therefore, what do you think will happen if the temperature is increased? (*giving a clue*).
Sade: I think the equilibrium will shift to the left i.e. backward reaction will be favoured.
Teacher: This is a wonderful response, clap for Sade. Now let us consider this:

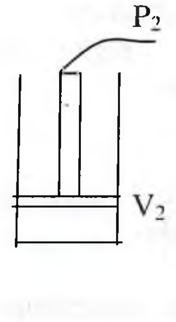
$$2H_{2(g)} + O_{2(g)} \rightleftharpoons 2H_2O_{(g)}$$

What is the nature of the reactants and product in this reaction? Alima.

Alima: The substances are gases.
Teacher: Good. That is right. Which of the factor will affect the state of equilibrium of reactions involving gases? Kunle.
Kunle: Temperature.
Teacher: No, you should know that the ΔH is not given.
Kunle: Pressure.
Teacher: Good. You are correct. Now listen, what is the total number of volumes of the reactants and that of the products? Godspower come to the board and tell us.
Godspower (*writes*): 2 volume of H_2, and 1volume of O_2 and 2 volumes of H_2O.
Reactants: 2+1=3: Product:2
Teacher: Godspower is right .i.e. We have three volumes of reactants and two volumes of product.

Will the pressure increase or decrease if you reduce the volume? Sule.
Sule: The pressure will reduce (*incorrect and confused).*
Teacher: Sule listen, and look up.





V_2 is smaller than V_1, to get what V_2 what would you do to pressure

P_1? Sule you can answer *(providing hints and change stimulus to a simpler one).*

Sule: I will exert more pressure. That is, increase pressure.

Teacher: You are right. Now, from $2H_{2(g)} + O_{2(g)} \rightleftharpoons 2H_2O_{(g)}$.

Increase in pressure will favour which reaction, backward or forward? Kingsley.

Kingsley: Since increase in pressure will reduce the volume, therefore, increase in pressure will favour forward reaction.

Teacher: Excellent.

Let us look at change in concentration.

Consider $3Fe_{(s)} + 4H_2O_{(g)} \rightleftharpoons Fe_3O_{4(s)} + 4H_{2(g)}$.

At equilibrium, there is definite concentration of reactants and products. When the concentration of reactant is increased, there is proportionate increase in the products. Now, what happens to the equilibrium when more reactant is added? Kayode.

Kayode: The equilibrium shift to the right forming more products *(responds confidently)*

Teacher: Good response. What if I decide to remove hydrogen? Talata.

Talata: Concentration of product will be reduced *(a bit confused)*

Teacher: Yes, how will this affect equilibrium? *(probes further)*

Talata: Favours shift in equilibrium to the right.

Teacher: Correct. When more iron is added or hydrogen is removed, the reaction moves forward but when iron is removed or hydrogen gas is added that favours backward reaction.

Step 5: Teacher discusses application of Le Chatelier's principle with the students.

Teacher: Industrially, Le Chatelier's principle is applicable to reactions that involve minimizing the cost of production, maximizing the product and attaining equilibrium with the shortest possible time. For example, production of ammonia by Haber process and manufacture of Sulphur (VI) oxide by the Contact process.

Given: $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$ $-\Delta H$, how can you increase the yield of ammonia? John.

John: By lowering the temperature

Teacher: That is good. Why is it so? Kate.
Kate: Because the forward reaction gives off heat.
Teacher: Good, what do you call that type of reaction?
Kate: Exothermic reaction.
Teacher: Excellent. A brilliant girl. What is the effect of increase in pressure on the reaction? Mohammed.
Mohammed: It will slow down the production of ammonia.
Teacher: Mohammed, look at the volume of the reactants and that of product, because they are gases *(giving direction).*
Mohammed: We have four volumes of reactants and two volumes of products.
Teacher: If you increase pressure, what will happen to volume of the reactants?
Mohammed: It will reduce the volume *(building more confidence).*
Teacher: Good, now that the volume is reduced, will this favour the reactant or product.
Mohammed: It will favour the product which is increase in yield of ammonia.
Teacher: Clap for Mohammed.
Teacher then emphasize that to obtain high yield of ammonia, we consider temperature (450°C – 500°C), catalyst (iron) and pressure (200 – 250 atmosphere).

Teacher follows the same feedback and correctives strategy to explain the manufacture of Sulphur (VI) oxide as in $2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$ using Contact process.

Problems Affecting the Use of Corrective Feedback

Application of corrective feedback as a strategy to enhance understanding of chemistry students could be affected by inability of teachers to make contributions that would enable students to correct wrong responses. Delayed feedback is another problem in which the teacher may likely forget students' responses if the feedback is not immediate. This happens when teachers keeps quiet or gives negative feedback that discourage students from further contributions to classroom discussion. Not all students would want to respond to teacher's questions due shyness and lack of understanding of the questions. This also constitutes hindrance to flow of feedback and delay in the corrections been made. Since chemistry teachers deal with variety of students from different educational and environmental backgrounds, deriving the mode of interaction and feedback would be a problem. Chemistry teachers need to understand these problems so as to apply corrective feedback to Le Chatelier's principle instructional delivery in the class.

Conclusion

In order to ensure students' understanding and consequently boost their performance in Le Chatellier's principle, students' confusions could be removed by employing teacher-student interactive mode of instruction in the classroom. Feedback and correctives strategy discussed in this paper could encourage students' effective learning of the chemical concepts. It is a means for carrying along both low and high achieving chemistry students to actively participate in chemistry lessons. This strategy is not only applicable to classroom discussion but also could motivate students to follow the right steps during practical sessions as the chemistry teacher corrects mistakes of the students in handling laboratory equipment, observation and report writing. Chemistry teachers should therefore create an active learning classroom to increase students' understanding and assimilation by involving feedback with correctives in impacting knowledge on chemical reactions in general and Le Chatelier's principle in particular.

Recommendations

Suggestions for improving feedback include: (a) making detailed comments on students' responses that refer to additional sources for supplementary information; (b) give feedback without delay; (c) taking note of students who do not participate during the lesson and focusing questions on them to make active individually; and (d) integrating a variety of delivery systems for interaction and feedback, including one-one conference calls, e-mail and computer conferencing.

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