Developmental Level, Problem - Solving Skills and Perceptions in Learning Electrochemistry Using a Flipped Classroom Model

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Abstract: ***Problem- solving skills is very important in chemistry. Hence, students' problem - solving skills and developmental level were analyzed using flipped classroom model (FCM) as well their general perceptions. Two contrasted groups, Experimental Group (Flipped classroom) and Control Group (Conventional classroom) were used in the study. The respondents of the study were freshmen Civil Engineering students. Five factors of problem - solving skills were used as a scheme interpretation. Lastly, the developmental level was also determined before and after the intervention. The flipped class was of better problem comprehension and can relate chemical concepts to the problem than the conventional class. In both classes, students have misconception statements on the oxidizing - reducing agents and the flow of electrons in a cell. Nevertheless, the majority of the students can solve problems involving the standard and non - standard Ecell potential and Gibbs free energy (ΔG^o). The use of flipped classroom instruction garnered general positive perceptions. However, the developmental level of the students was not affected by the use of the flipped classroom. Most of the students were at a transitional level before and after the intervention. Students perceived that FCM improved independent learning, enjoyable, timely, engaging and that the use of FCM is a potential pedagogy to learn electrochemistry.***

Keywords: misconceptions, problem - solving, electrochemistry, developmental level, flipped classroom model

1. Introduction

Learning chemistry involves both algorithmic (or problem - solving) and conceptual understanding skills. These are essential skills in quantitative problems such as electrochemistry. Yet, many students have many misconceptions and have many problem - solving difficulties. Electrochemistry is an interconversion of electrical energy and chemical energy in a redox reaction. Behind the function of the battery, purifying of metals, decreasing metal corrosion, and production of electricity are some of the few practical importance of electrochemistry. Hence, a day without electricity from either the Power Company or batteries is unimaginable in our technological society (Chang, 2012). In studying electrochemistry, students need to understand both microscopically and macroscopically. Macroscopically is the study of electrolytes and non - electrolytes, the electrolysis process, and voltaic cells. The study of the movement of ions and electrons during the electrolysis process falls microscopically. However, students face difficulties in understanding the abstract chemical processes especially at the microscopic and symbolic levels (Garnett *et al.*, 1995; Garnett & Treagust, 1992b; Lee *et al.*, 2011; Lin *et al.*, 2003; Sanger & Greenbowe, 1997a; Sanger & Greenbowe, 1997b). The study of Huddle & White (2000) presented that electrochemistry is challenging to learn because the concepts are abstract, and the language of chemistry is new. According to Özkaya *et al.*, (2006) for instance, ions and electrons are invisible to the eye, and thus, teaching about them requires a teacher to be creative. The concept of the connection between cell voltage and the relative strength of the oxidant and reductant was rated as the most challenging topic to understand (Butts & Smith, 1987). Ceyhun and Karagolge (2005) study suggested that students who have misconceptions were still able to calculate cell potentials correctly. Özkaya (2002) attributed learning difficulties in electrochemistry to a general lack of conceptual understanding and attributes this to insufficient textbook explanations of the concepts. Furthermore, Sanger & Greenbowe (2000) suggest that novice learners need to watch for relevant details to maximize their learning experience while using computer animation. Huddle *et al.*, (2000) also added that students gain more from a hands - on manipulation of a concrete model. Studies show that electrochemistry is of abundance in student - held misconceptions. The misleading and use of vague terminologies cause this misconception and it enlarges students' general confusion (Acar& Tartan, 2006; Sanger & Greenbowe, 1999b). The term anode on the "left side" of the voltaic cell is another confusing term (Sanger & Greenbowe, 1999b). The "left side" infers the location of a particular oxidation (or reduction) reaction that occurs in which students hard to recognize. Another confusing meaning is the use of an electrolytic cell. In an electrolytic cell, the ions out of molten salt (or a solution) are produced, and elemental (or solid) substances are formed via oxidation or reduction. A cathode electrode may reapply in another context. In an electrolytic cell, the cathode is the negative terminal electrode while in voltaic cell it is in a positive electrode (Schmidt *et al.*, 2007).

In the study of Sanger & Greenbowe (1997a) they enumerated several alternative misconceptions. These include that electrons move in a solution by being attracted from one ion; anions transfer electrons from the cathode to the anode in the salt bridge; electrons flow in an aqueous solution without assistance from the atoms; the anode is positively charged because it has lost electrons; and the cathode is negatively charged because it has gained electrons (Sanger & Greenbowe, 1997a).

Since electrochemistry topped as one of the most challenging topics in chemistry, various teaching techniques have been introduced to improve algorithmic skills and to correct misconceptions. Thompson & Soyibo (2002) administered a practical work approach, and it showed an improvement in students' test scores and attitudes toward chemistry. Özkaya *et al.*, (2006) used two - tier assertion - reason style problems to assess learning better and to uncover misconceptions. Explicitly informing the students about common misconceptions during instruction was an approach used by Ogude & Bradley (1996) which was a success in improving conceptions. Analogies can be made to macroscopic phenomena to visualize abstract electrochemistry concepts. For example, the attraction of a positively charged particle and a negatively charged particle can be compared to the attraction between opposite poles of a magnet (Brown *et al.*, 2006). Visible effects resulting from submicroscopic particle interactions can be demonstrated, as in the case of new and different - looking products formed in a chemical reaction (Brown *et al.*, 2006). But regularly, a ball and stick models, help visualize molecular shapes (Brown *et al.*, 2006) as a resort of most chemistry teachers. The use of analogies in the form of concrete models when teaching theoretical chemical concepts, aids in the development and refinement of ideas, and remediating misconceptions (Huddle & White, 2000). The use of analogies also provides students with a level of comfort and security that enables them to connect what they know with the world of theories and abstractions.

Flipped Classroom Model

In this time of the pandemic, face - to - face teaching - learning is impossible to realize. Many schools around the world opted to use technology to deliver essentially lessons to the learners. Hence, many educators opted to integrate flipped classroom model in their learning modules. This is also to address the suggestion that teachers are required to look into different teaching strategies to address these challenges such as the use of technology (Necor, 2018). The flipped classroom is a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space. Currently, flipping the classroom has become an increasingly popular approach for college students - teachers' role changes from lecturer and deliverer to learning content coach. Bergman & Sams (2002), authors of flipped classrooms, suggested that this is beneficial to students and professionals' development settings, particularly those who are busy, as videos are viewed at a convenient time, whether at home, workplace, or mobile device while traveling. Struggling learners can stop, pause, and replay as many times as needed, which leads to a higher level of transparency and specificity. Hence, flipped classroom has recently a trend in teaching - learning worldwide.

2. Conceptual Framework

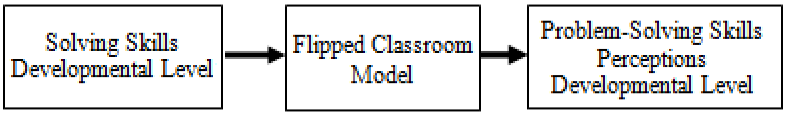


Figure 1: The conceptual framework of the study

Problem - solving skills are the main goals in learning chemistry. It infers how the students solve problems in an effective and timely manner without any impediments. This is how the students can identify and define the problem, generating alternative solutions, evaluating and selecting the best alternative, and implementing the selected solution. Currently, flipping the classroom has become an increasingly popular approach for college students. Many educators around the world shifted to teach students with the use of technology and impacted significantly on the student's performance. The direct instruction moves from the group learning space to the individual learning space. The resulting group learning space is transformed into a dynamic and interactive learning environment. The usual lecture and assignments elements of a course are reversed. Thus, the students learned independently and effectively.

The study of Moore (2012) suggested that the majority of non - STEM students can be classified as either concrete operational or transitional reasoners in Piaget's theory of cognitive development. Lawson suggests that scientific reasoning has a structure that is chiefly hypothetic - deductive and consisting of interrelated aspects, such as proportional reasoning, control of variables, probability reasoning, and correlation reasoning (Lawson, 2000). He further cited that, in particular, student views about science greatly influence their ability to "create new knowledge," where students limit themselves to specific modes of knowledge construction. Even students that hold more constructivist views of science overall can similarly limit themselves when confronted with particular problems and situations. Piaget's theory of cognitive development includes classification into two formal reasoning levels (concrete operational and formal operational) with a transitional stage between the two (Inhelder & Piaget, 1958).

However, Moore (2015) suggested that students struggle with solving problems outside of a specific context, demonstrating significant difficulty with abstract concepts and hypothetical tasks. Formal operational reasoners begin to think abstractly, reason logically, and draw conclusions from available information. Furthermore, unlike the concrete operational reasoner, they can apply appropriate logic to hypothetical situations in most contexts (Moore, 2015).

3. Objectives of the Study

This study was conducted to assess the effectiveness of FCM on the problem - solving skills of freshmen engineering students in electrochemistry. The student's developmental level before and after the intervention, and student's perceptions of FCM were also carried out in this study.

4. Methodology

This study used a quasi - experimental design to compare students' problem - solving skills and developmental levels. Two contrasted specified instructional models – conventional (control) and flipped classroom model (experimental) were utilized. The selection of students was made via a purposive sampling technique based on the criteria appropriate for the study. In the flipped classroom, each student is required to have online access outside classes to each video posted. All the students in the flipped classroom were enrolled in the Google classroom created by the researcher. The videos were downloaded from YouTube from reputable sources. All the videos were pre - watched before posting. A survey questionnaire was given to gather students' perceptions concerning the flipped classroom instruction after the intervention.

5. Research Instruments

5.1 Problem - Solving Skills

5.1.1. Electrochemistry Problem - Solving Ability Test (EPSAT)

In this study, an Electrochemistry Problem - Solving Ability Test (EPSAT) developed by the researcher was used as a pretest/posttest. Scores of the student in the test were interpreted as his/her problem - solving ability in electrochemistry. This test serves as a basis for students' problem - solving skills and conceptual understanding in electrochemistry after interventions to both groups. The test was content - validated by chemistry education experts who have been teaching chemistry for over five years. The test is suitable for two hours. Scores were based on a rubrics scoring scheme based on how and what students included in their solutions and the problem - solving skills required/or demonstrated with each score. The percentage correct responses of students were obtained and transcribed carefully.

The EPSAT consisted of seven problems, which each includes of sub - questions. Each sub - questions were used to assess such as (a) problem comprehension; (b) understanding relationships among chemical concepts; (c) understanding associated chemical concepts; (d) applying specific problem - solving strategies; and (e) using required mathematics. Table 1 shows a sample problem in EPSAT.

Table 1: EPSAT sample problems

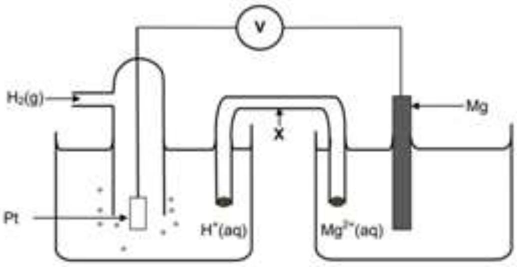
The reaction below occur in a cell at 25ºC has a concentration of 0.60 M for [Fe^{2+}] and 0.010 M for [Cd^{2+}].

$$Cd\ (s) + Fe^{2+}\ (aq) \rightarrow Cd^{2+}\ (aq) + Fe\ (s)$$

a) What is the half - cell reaction and standard emf (E^0) of the cell?
b) What is the nonstandard emf (E) of the cell?
c) Will the reaction occur spontaneously? Why?

The galvanic cell represented below consists of hydrogen half - cell and a magnesium at standard condition. The reading on the voltmeter is 2.37V.

a) What is the name of the apparatus labeled X in the diagram above? What are its main functions?
b) Is magnesium the ANODE or CATHODE in the cell above? Explain your answer.
c) What is the cell notation for this cell?
d) What is the net (overall) cell reaction that takes place in this cell?



5.1.2 Problem - Solving Ability Rubric (PSAR)

The Problem - Solving Ability Rubric (PSAR) as cited by Gayon (2004) was used to quantify the problem - solving skills such as their conceptual understanding, strategies, and mathematical abilities. The problem comprehension and understanding of relationships among chemical concepts were also quantified. Each solution was characterized by five (5) factors, as shown in Table 5. A maximum of three (3) points for each factor was used with a total of 15 - points for each problem. Students' performance in each factor was interpreted, as shown in Table 2.

Table 2: Scoring scheme and interpretation in each factor of EPSAT

Percentage Score	Verbal Interpretation
81 - 100	Outstanding
61 - 80	Very Satisfactory
41 - 80	Satisfactory
21 - 40	Fair
0 - 20	Poor

5.1.3. Factors Underlying Electrochemistry Problem - Solving Ability Test (EPSAT)

In this study, five factors were utilized as a basis for problem - solving skills. It includes (a) Problem Comprehension; (b) Understanding Relationships Among Chemical Concepts; (c) Understanding Associated Chemical Concepts (d) Applying Appropriate Problem - Solving Strategies; and (e) Using Appropriate Mathematics. The effectiveness of FCM in learning electrochemistry was determined by weighted scores in EPSAT. An independent two - sample ***t*** - test at a 5% level of significance was used to compare their scores for each factor using pre - test/posttest scores.

Factor a: Problem Comprehension

It refers to the ability of the students to understand the problem by extracting and interpreting meaning from an expression or message. It involves the translation of chemical names to symbols, identifying variables to be solved or relevant variables needed to solve the problem, and considering constraints in the problem.

Factor b: Understanding Relationships Among Chemical Concepts

It refers to the ability of students to understand and apply the associated concepts (Molarity; Voltage; standard/ nonstandard electrode potential, spontaneity) to the problem. It involves the selection and implementation of relevant chemical concepts without any misconceptions.

Factor c: Underlying Associated Chemical Concepts

It refers to the ability to relate concepts involved in the problem. The concepts or quantities may be directly or indirectly stated in the problem. It is measured in terms of the number and correctness of relevant relationships among the chemical concepts. For example, correct explanation about reducing/oxidizing agents, the flow of electron in the cell, and spontaneity of the cell.

Factor d: Applying Appropriate Problem - Solving Strategies.

It involves the ability to select and implement a strategy that shows how the solution progresses from goal to general concepts and to arrive at a correct answer. For instance, can choose an appropriate strategy (e. g., calculation of *emf*; determine the net reactions; draw and label the Galvanic cell) needed to solve the problem.

Factor e: Using Appropriate Mathematics

It accounts for students' mathematical skills as applied to the specific problem. It probes the solution to the problem following numerical (e. g., algebraic and arithmetic) rules. It also involves a demonstration of understanding through the consistent use of mathematical language. In this study, the students can understand and apply relationships among numbers. In the sub - questions on Electrochemistry, the students are required to determine the emf; Gibbs free - energy (ΔG^0); the anode and cathode; and electrode potential. It inferred that students would not be able to solve the problem correctly, even if they know the concept behind it.

Table 3: Problem - Solving Ability Rubric (PSAR) for problem 5 (factor a, b, c, d and e)

Level of Performance (Score)	Factor (a) Problem Comprehension	Factor (b) Understanding Relationships Among Chemical Concepts	Factor (c) Understanding Associated Chemical Concepts
3	• Identifies what is to be computed for in the problem • Supports answer with correct computation in cell voltage at standard and nonstandard condition	• Solution includes at least 4 relevant relationships among chemical concepts (e. g. net equation and spontaneity of redox reaction) • Gives correct relationship between reduced and oxidized and electron flow • Gives correct explanation in the spontaneity of the redox reaction	• Selects and implements the relevant chemical concepts without any conceptual errors (e. g. spontaneity of the redox reaction)
2	• Identifies what is to be solved but fails to give an accurate answer. • Does not support answer with computation	• Solution includes 3 relevant relationships among chemical concepts • Gives correct relationship between the spontaneity of the reaction but fails to explain correctly.	• Evidence that the student has misconceptions • Fails to consider a relevant concept needed to solve the problem correctly
1	• Fails to give an accurate answer and/or solution to either question. • Gives partially correct answer.	• Solution include 1 or 2 relevant relationships among chemical concepts • Fails to give correct relationship spontaneity of the redox reaction in a cell.	• Evidence that the student has several misconceptions • Fails to consider several concepts needed to solve the problem correctly
0	• Nothing written • Complete misunderstanding of the problem • Only repeats information in the problem	• Nothing written • Fails to give correct relationship	• Nothing written • Only repeats information in the problem • Gives a wrong answer and fails to show solution

Level of Performance (score)	Factor (d) Applying Appropriate Problem - Solving Strategies	Factor (e) Using Appropriate Mathematics
3	• Selects and implements appropriate strategy (e. g. breaking the problem into steps, identifying sub - goals) needed to solve the problem • Solution progresses from goal (e. g. Standard electrode potential) to general concepts (e. g. non - standard electrode potential)	• Mathematics is correct; numbers are either substituted at each step or at the last step • Demonstrates understanding through consistent use of mathematical language and able to derive the *Nernst* equation and correctly substituting the values given.
2	• Fails to carry out the strategy far enough (e. g. computation only up to cell voltage and net cell equation) • Plan could gave led to a correct solution if implemented properly	• Sparse use of language (e. g. numbers sense, number relationships, operations, algebra, or arithmetic) • Solution violates mathematics (e. g. algebra, arithmetic)
1	• Solution does not proceed past basic statement of concepts (e. g. cell voltage in standard condition) • Partially correct plan based on part of the problem being interpreted correctly	• Solution terminates for no apparent reason. • When an obstacle is met, “math magic” or other unjustified relationship occur. • When an obstacle is met, solution stops. • Serious math errors in cell voltage and *Kc* of cell voltage
0	• Nothing written • Difficult to assess • Inappropriate strategy	• Nothing written • Used no mathematical language inaccurately

5.2 Students’ Perceptions on Flipped Classroom Instruction

The Problem - Solving Ability Rubric (PSAR) as cited by Gayon (2004) was used to quantify the problem - solving skills such as their conceptual understanding, strategies, and mathematical abilities. The problem comprehension and understanding of relationships among chemical concepts were also used. Each solution was characterized by five (5) factors, as shown in Table 5. A maximum of three (3) points for each factor was used with a total of 15 - points for each problem. Students’ performance in each factor was interpreted, as shown in Table 2.

Table 4: Rubric in Converting Mean Score to Students’ Perception Under Flipped Classroom Model

Mean Score	Verbal Interpretation
4.50 - 5.00	Strongly Agree
3.50 – 4.49	Agree
2.50 – 3.49	Neither Agree or Disagree
1.50 – 2.49	Disagree
0.00 – 1.49	Strongly Disagree

5.3 Developmental Level

A Lawson Classroom Test of Scientific Reasoning (LCTSR, 2000) was used to match the participants in both groups and to determine their developmental level before and after the intervention. The scores were also served as the basis to identify who were the students to become part of the respondents. The LCTSR, 2000 is a revised two - tier multiple - choice edition consisting of 24 questions. This test is designed to assess students' scientific reasoning ability. The LCTSR 2000 determines six dimensions of scientific ability. These include conservation of matter and volume, proportional reasoning, control of variables, probability reasoning, correlation reasoning, and hypothetical - deductive reasoning. Using LCTSR 2000, students' scores can be classified into three formal reasoning categories, as shown in Table 5, as suggested by Lawson *et al.*, 2000. A student must correctly answer both questions within a scenario to receive one - point credit. The correct percent was based on the 12 scenarios.

Table 5: LCTSR 2000 Scores’ Classification

Verbal Interpretation	Percentage Correct	Range Scores
Concrete Operational (EI) Reasoning (*Empirical - Inductive*)	0% - 25.00%	0 - 3
Transitional Operational (TR) Reasoning (*Transitional*)	33.33% - 66.67%	4 - 8
Formal Operational (HD) Reasoning (*Hypothetical - Deductive*)	Above 75%	9 - 12

5.4 Intervention Strategies

In both groups, the intervention was carried out for 16 hours. Two constructed teaching pedagogy were used: the flipped classroom model and conventional model instruction were administered in the experimental group and control group, respectively. In the flipped class, students were required to watch videos and presentations before in - class at their pacing. The students can browse, watch, or listen to the videos several times. Assignments were assigned which is tailored. A total of 25 video lectures were posted over the course. The videos were downloaded from reputable sources and pre - screened by the researcher before posting. The videos were more specific and covered one or two topics. Guided notes were also available to help students take notes and focus on critical elements in the video lecture. The topics were also mirrored to those of the lectures that were delivered in the control class.

6. Results and Discussion

6.1 Problem - Solving Skills

The EPSAT was evaluated for each factor underlying problem - solving skills using a PSAR. Table 6 shows that the experimental group has a weighted mean score of 29.43 (or 84.08%) of the 49 points maximum score indicating an outstanding interpretation (Table 2). On the other hand, the control group has a very satisfactory interpretation (Table 2) whose weighted mean score of 26.31 (or 75.18%) of the 49 points maximum score. The experimental group has outstanding problem comprehension. They have also an outstanding ability to understand the relationship between chemical concepts and to apply appropriate mathematical calculations in most problems. Conversely, the control group has a general scheme of very satisfactory and only two factors (factor d and e) have an outstanding general scheme.

Table 6: Mean and percentage score in EPSAT for each Factor

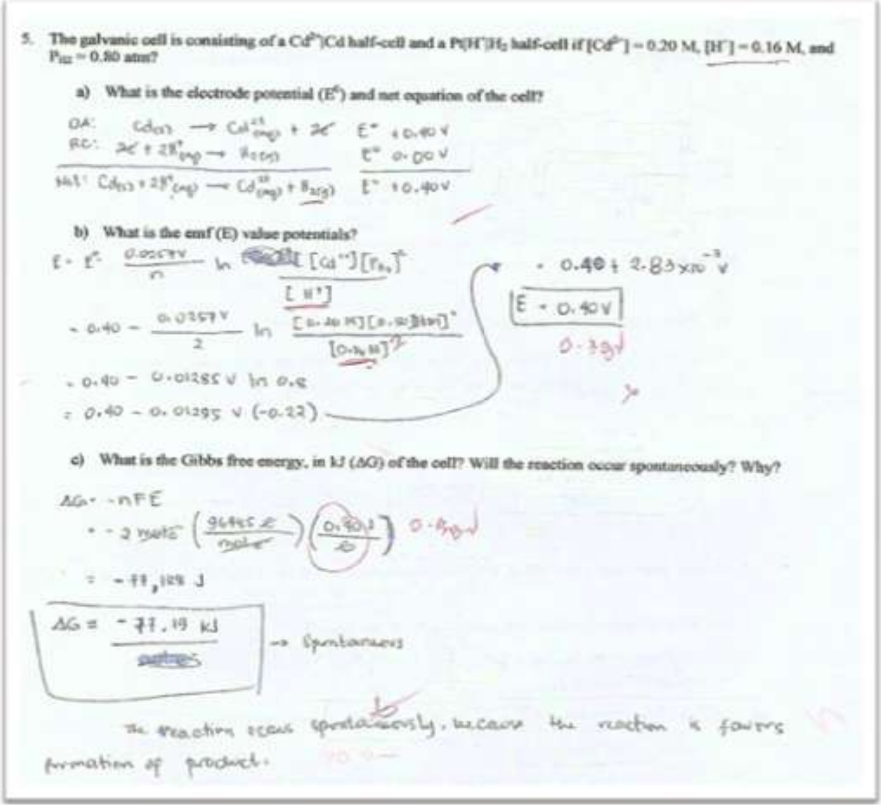
EPSAT Factor	Number of Items	Maximum Possible Score	Mean Score		Percentage Correct	
			Experimental	Control	Experimental	Control
a. Problem Comprehension	7	49	30.29	26.71	86.53	76.33
b. Understanding Relationships among Chemical Concepts	7	49	28.29	24.29	80.82	69.39
c. Understanding Associated Chemical Concepts	7	49	22.71	23.43	64.90	66.94
d. Applying Appropriate Problem - Solving Strategies	7	49	32.00	28.14	91.43	80.41
e. Using Appropriate Mathematics	7	49	33.86	29.00	96.73	82.86
Total	35	245	29.43	26.31	84.08	75.18

Table 7: Independent Sample *t* - test Comparing Each Factor of Experimental and Control Group

Factor	Group	N	Mean	SD	SE	t	p= Value	
a. Problem Comprehension	Experimental	14	2.163	.7557	0.076	2.33	.0103<p=.05	S
	Control	14	1.908	.7744	0.078			
b. Understanding Relationships among Chemical Concepts	Experimental	14	2.02	.7319	0.074	2.61	0.0049<p=.05	S
	Control	14	1.735	.7937	0.080			
c. Understanding Associated Chemical Concepts	Experimental	14	1.622	.7932	0.080	1.15	0.126>p=.05	NS
	Control	14	1.490	.8151	0.082			
d. Applying Appropriate Problem - Solving Strategies	Experimental	14	2.286	.8249	0.083	2.25	0.0128<p=.05	S
	Control	14	2.01	.8909	0.090			
e. Using Appropriate Mathematics	Experimental	14	2.418	.8113	0.082	2.82	0.0027<p=.05	S
	Control	14	2.071	.9111	0.092			

Legend: S=significant, NS= Not significant

Table 7 shows a *t* - test for independent samples to compare the mean scores for each factor in all items in both groups. Factors *a*, *b*, *d*, and *e* have a significant difference based on the mean scores while factor c has no significant difference between the two groups. This suggests that the group under flipped classroom model performed better than conventional instruction. It was reiterated that flipped class can relate chemical concepts to the problem. They can also perform and apply appropriate algorithmic calculations to the question as compared to the control group (conventional class). Hence, flipped classroom model is highly recognized as an effective teaching pedagogy in recent modalities. However, in both groups, there was no significant difference in terms of how the student explain the underlying concepts.



5. The galvanic cell is consisting of a $Cd^{2+}|Cd$ half-cell and a $Pt|H^{+}|H_2$ half-cell if $[Cd^{2+}] = 0.20$ M, $[H^{+}] = 0.16$ M, and $P_{H2} = 0.80$ atm?

a) What is the electrode potential (E^0) and net equation of the cell?

OA: $Cd_{(s)} \rightarrow Cd^{+2}_{(aq)} + 2e^-$ E° +0.40 V
RC: $2e^- + 2H^+_{(aq)} \rightarrow H_{2(g)}$ E° 0.00 V
Net: $Cd_{(s)} + 2H^+_{(aq)} \rightarrow Cd^{+2}_{(aq)} + H_{2(g)}$ E° +0.40 V

b) What is the emf (E) value potentials?

$E = E^\circ - \frac{0.0257V}{n} \ln \frac{[Cd^{+2}][P_{H_2}]}{[H^+]}$
$= 0.40 - \frac{0.0257V}{2} \ln \frac{[0.20 M][0.80 atm]}{[0.16 M]^2}$
$= 0.40 - 0.01285 V \ln 0.8$
$= 0.40 - 0.01285 V (-0.22)$
$= 0.40 + 2.83 \times 10^{-3} V$
$\boxed{E = 0.40 V}$
0.39✓

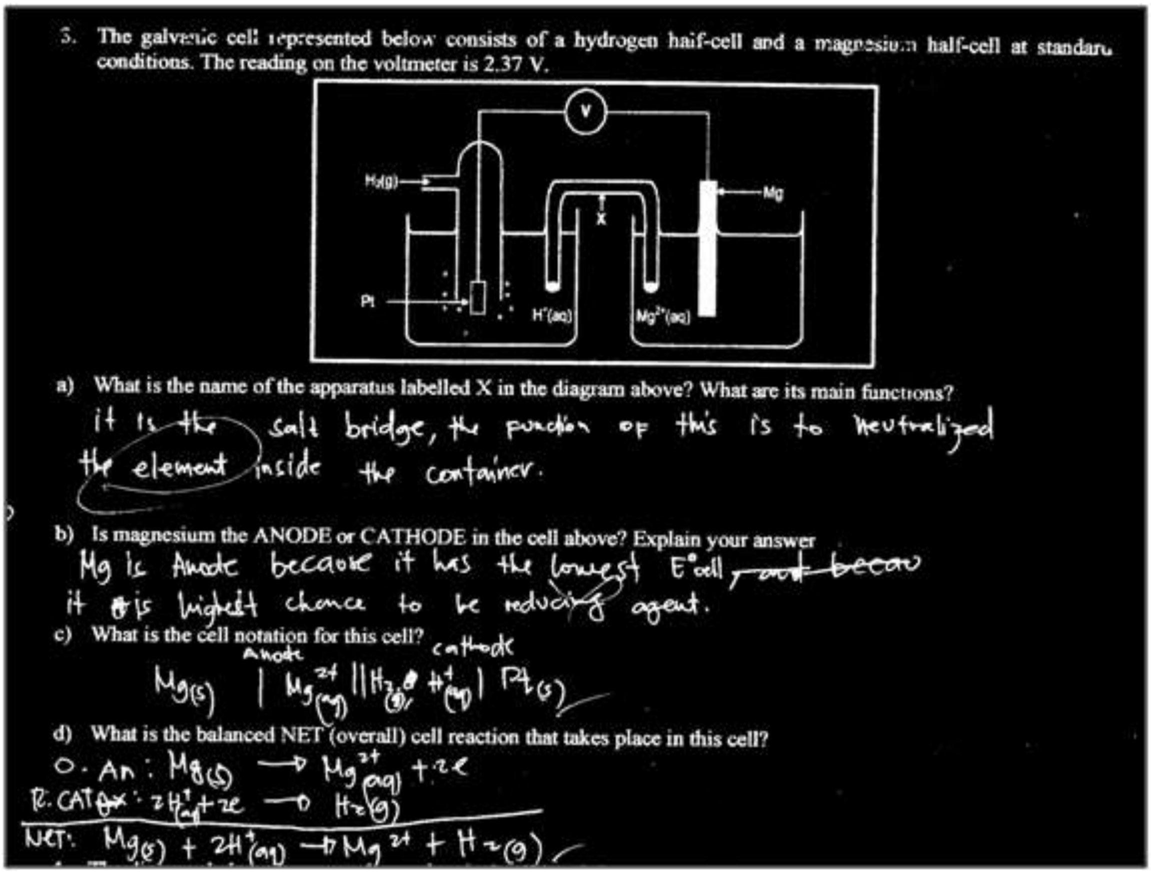
c) What is the Gibbs free energy, in kJ (ΔG) of the cell? Will the reaction occur spontaneously? Why?

$\Delta G = -nFE$
$= -2$ moles $\left(\frac{96485 C}{mole}\right)\left(\frac{0.40 J}{C}\right)$ 0.40✓
$= -77{,}188$ J
$\Delta G = -77.19$ kJ → Spontaneous

The reaction occurs spontaneously, because the reaction is favors formation of product.

Figure 2: A sample answer on Thermodynamics of Redox Reactions by E#21

Figure 2 shows a sample answer by student E#21. Though most of the students are capable of doing mathematical calculations however, some students cannot perform an appropriate strategy. In a sample answer, E#21 failed to identify sub - goals needed to solve the problem like the number of concentrations [H^+] ions. Hence, he failed to multiply the concentration of [H^+] ions by two. This affects the *emf* value at the nonstandard condition and succeeding calculation like the value of the Gibbs free energy (ΔG). In this case, he is unaware that the number of [H^+] ions is doubled based on the net cell equation [$Cd_{(s)} + 2H^+_{(aq)} \rightarrow Cd^{2+}_{(aq)} + H_{2\ (g)}$] even though he identified what is to be solved but fails to give an accurate answer. This result of the study is consistent with the study of Ceyhun and Karagolge (2005). They supported the idea that students who have alternative conceptions in electrochemical concepts were still able to calculate correctly.



3. The galvanic cell represented below consists of a hydrogen half-cell and a magnesium half-cell at standard conditions. The reading on the voltmeter is 2.37 V.

a) What is the name of the apparatus labelled X in the diagram above? What are its main functions?

it is the salt bridge, the punction of this is to neutralized the element inside the container.

b) Is magnesium the ANODE or CATHODE in the cell above? Explain your answer

Mg is Anode becaose it has the lowest E°cell, ~~and becau~~ it is highest chance to be reducing agent.

c) What is the cell notation for this cell?

Anode cathode

$Mg_{(s)} \mid Mg^{2+}_{(aq)} \parallel H_{2(g)}, H^+_{(aq)} \mid Pt_{(s)}$

d) What is the balanced NET (overall) cell reaction that takes place in this cell?

O. An: $Mg_{(s)} \rightarrow Mg^{2+}_{(aq)} + 2e$

R. CAT: $2H^+_{(aq)} + 2e \rightarrow H_{2(g)}$

NET: $Mg_{(s)} + 2H^+_{(aq)} \rightarrow Mg^{2+} + H_{2(g)}$

Figure 3: A sample answer in EPSAT by student E#6

Figure 3 shows how student E#6 answers one of the problems in EPSAT. It shows that students are still able to write the line notation and net cell notation correctly even with misconception statements. In this problem, students were asked about the main functions of the salt bridge (marked X in the diagram). Some students just explain to gain marks even their answers are not scientifically accepted. Apparently, E#6 fails to consider the relevant concept needed to explain why Mg falls in the anode of the cell. He considered the $E^0_{reduction}$ (- 2.37V) value to explain that Mg is in the anode of the cell. According to Chang (2012), a species falls in the anode when it loses electron/s like the Mg. This concept falls in the microscopic explanation of the electrochemistry - the movement of electrons in a cell. Ergo, electrochemistry is one of the most challenging topics in chemistry.

Misconceptions Statements

After the intervention, misconception statements were identified and transcribed. Table 8 shows lists of misconception statements held by the students. Many students cease to explain as they do not understand the underlying concepts. The misconception statements of the students were shown in Table 8. Among the topics in electrochemistry, many misconception statements were found about the purpose of the salt bridge in the galvanic cell. The flow of electrons in an Ag^+/Cu^{2+} cell was also least understood as well as the use of Pt as a preference in a galvanic cell.

Table 8: Misconception statements held by the students

Questions	**Misconception Statements (verbatim)**
What are the oxidizing and reducing agents in an equation below? Explain $Cu_{(s)} + NO_3^-{}_{(aq)} \rightarrow Cu^{2+}_{(aq)} + NO_{2\ (g)}$	• NO_3^- is an oxidizing agent because N losses electron while Cu is a reducing agent because Cu gains electron. • NO_3^- causes reduction while Cu causes oxidation.
What are the main functions of salt bridge in a cell?	• It balances the charges between two elements. • Balance the flow of electrode in the Galvanic cell

	• It is used to balance the metabolic charges. • Maintain the flow of electron from anode to cathode • Maintain the neutrality of an electron • Maintain the neutrality of chemical reaction so that the solution will not mix • So that the flow of electrons became spontaneous
In a cell diagram, whose E° are shown below, in which direction do the electrons flow? Explain $\mathrm{Ag^+} + \mathrm{e^-} \rightleftharpoons \mathrm{Ag}$ $E^\circ = +0.80$ V $\mathrm{Cu^{2+}} + 2\mathrm{e^-} \rightleftharpoons \mathrm{Cu}$ $E^\circ = +0.34$ V	• From Ag to Cu because silver is less reactive than copper, so copper accepts electron. • From Ag to Cu because Ag loses electrons • From Ag to Cu because in the cathode electrons increases while in the anode, electrons decreases. • Anode to Cathode because
Why is Platinum used as preference when the reaction does not involve a metallic element?	• Because Pt is a good conductor of electrons • Because Pt can easily transfer electrons • Because Pt is a good conductor of electricity • Because Pt easily releases electrons • Because Pt is a good catalyst for a nonmetallic element • Because Pt is abundant and cheapest metal

Developmental Level

Both the experimental and control group took the LCTSR (2000) before and after the intervention. A table 9 show that in both groups, the p - value is greater than.05 signifies that there was no significant difference before and after the intervention. Only a minimal increase in their scores was noticed after the intervention. It suggested that the FCM pedagogy is not sufficient to raise any students from his or her cognitive level. Those who were classified as transitional remained transitional. The treatment is too short to expect any shift to a higher cognitive level.

Table 9: An independent *t* - test on LCTSR before/after intervention

LCTSR Test	Group	N	Mean	SD	*t*	p= Value	
a. Before Intervention	Experimental	14	4.25	.29	- .17	.43>p=.05	NS
	Control	14	4.29	.37			
b. After Intervention	Experimental	14	4.14	3.05	- .83	.20>p=.05	NS
	Control	14	4.64	1.94			

NS=Not significant

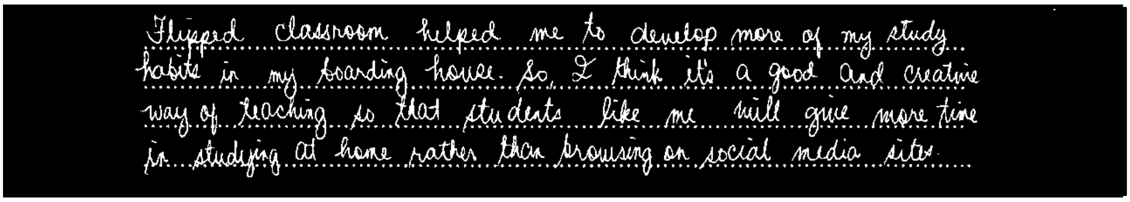
Students' Perception on the Used of Flipped Classroom Model

The student's perceptions in a flipped classroom instruction were obtained and transcribed. Table 10 presents students' perception of learning electrochemistry in a flipped classroom environment. It offers significant feedbacks on the use of flipped classroom instruction, which are vital importance in undertaking this teaching pedagogy.

Table 10: Students' Perception on the Use of FCM

Description	Mean	Verbal Interpretation	Rank
The Flipped Classroom…			
helped me understand concepts in electrochemistry easily.	4.32	Agree	1
helped me develop my study habits at home.	4.29	Agree	2
was enjoyable and interesting method of teaching.	4.25	Agree	3.5
helped me develop a positive attitude towards chemistry.	4.25	Agree	3.5
is more engaging than traditional classroom instruction.	4.21	Agree	5
increased my appreciation in learning electrochemistry.	4.18	Agree	6
encouraged me to study independently.	4.14	Agree	7.5
made me use my study time more essentially.	4.14	Agree	7.5
helped me gain a clearer understanding of the lesson.	4.11	Agree	9
gives me greater opportunities to communicate with other students.	4.07	Agree	10.5
should be used by other teacher to teach other topics in the future.	4.07	Agree	10.5
was able to choose how much I want to learn in a given period.	4.04	Agree	12
made me more mentally active in the learning process.	4.00	Agree	13.5
was appropriate strategy in learning chemistry effectively.	4.00	Agree	13.5
was able to decide when I want to learn.	3.93	Agree	15
Composite Mean	**4.14**	**Agree**	

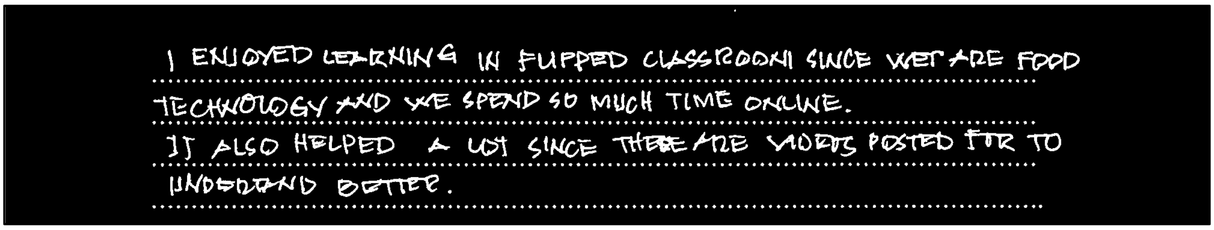
As shown in Table 10 the fifteen statements describing the flipped classroom instruction have a composite mean value of 4.14 indicating that the respondents agreed to most of the statements. Most of the students believed that FCM helped them understand electrochemistry easily. They also agreed that it developed their study habits at home and considered that FCM was an enjoyable and interesting method of teaching. It is further suggested by student E#8, as shown in *Figure 4*. He further suggested that FCM gave him ample time to study rather than spending more time on social sites.



Flipped classroom helped me to develop more of my study
habits in my boarding house. So, I think it's a good and creative
way of teaching so that students like me will give more time
in studying at home rather than browsing on social media sites.

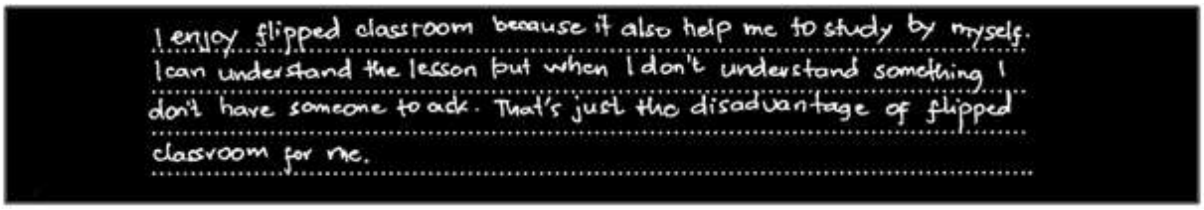
Figure 4: A sample response by student E#8 about the use of FCM

Another student also reiterated that FCM is enjoyable and likable, as shown in *Figure 5*. She suggested that it helped her a lot in understanding electrochemistry better because of the videos that she watched. This was also suggested by student E#13, as shown in *Figure 6*. She also said that FCM improved her independent learning. However, she pointed out that one of the drawbacks of FCM was that no one will answer directly her query about the lesson.



I ENJOYED LEARNING IN FLIPPED CLASSROOM SINCE WE ARE FOOD
TECHNOLOGY AND WE SPEND SO MUCH TIME ONLINE.
IT ALSO HELPED A LOT SINCE THERE ARE VIDEOS POSTED FOR TO
UNDERSTAND BETTER.

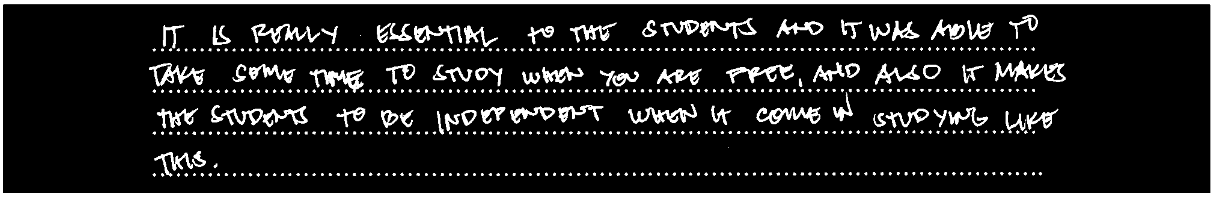
Figure 5: A sample response by student E#21 about the use of FCM



I enjoy flipped classroom because it also help me to study by myself.
I can understand the lesson but when I don't understand something I
don't have someone to ask. That's just the disadvantage of flipped
classroom for me.

Figure 6: A sample response by student E#13 about the use of FCM

Student E#2 considered that FCM was an essential pedagogy because it gave her ample time to learn the lesson in her spare time, as shown in *Figure 7*. She also believed that it developed her independent learning as also suggested by student E#8.



IT IS REALLY ESSENTIAL TO THE STUDENTS AND IT WAS ABLE TO
TAKE SOME TIME TO STUDY WHEN YOU ARE FREE, AND ALSO IT MAKES
THE STUDENTS TO BE INDEPENDENT WHEN IT COME IN STUDYING LIKE
THIS.

Figure 7: A sample response by student E#2 about the use of FCM.

Generally, FCM paved away the conventional teaching - learning in electrochemistry. Ergo, flipped classroom instruction is another method that a teacher to look into.

7. Conclusion

The Flipped Classroom Model performed better than Conventional Classroom in problem - solving skills. The flipped classroom class was of better problem comprehension and can relate chemical concepts to the problem. They can also perform and apply appropriate algorithmic calculations to the question as compared to the control class. In both classes, the students can able to solve algorithmic problems such as *E*°cell potential. They can also solve problems in equilibrium constant (*Kc*) in the cell and determine the spontaneity of the reaction. They can derive and solve problems involving standard and non - standard free energy ($\Delta G°$) in a cell. However, many students cannot distinguish the spontaneity of the redox reaction. They have difficulty in writing the correct net equation and line notation in a cell. They also have confusion on the direction of ions in the salt bridge, as well as labeling correctly the Galvanic cell. However, there was no significant difference in terms of how the student explains the underlying concepts, in which many students hold misconceptions statements. Many students could not explain correctly why species serve as oxidizing and reducing agents in a redox reaction. Students also have difficulty in explaining the flow of electrons in a cell. Amongst the five factors, factors d (applying appropriate problem - solving strategies and e (using the suitable mathematical solution) were held as the highest in both groups. However, factor c (understanding associated chemical concepts) garnered as the lowest percentage correct in both groups. The FCM pedagogy is not sufficient to raise any students from his or her cognitive level. Those who were classified as transitional remained transitional. The majority of the students agreed about the use of Flipped classroom instruction as an effective way to learn electrochemistry. This study affirmed that students appreciate a diverse approach to teaching, learning, and showing what they know. With the advances of new educational technologies and social media, the options to provide a rich learning experience for today's students may be limitless. The flipped classroom model is one method teachers should consider as a vehicle to expose students to relevant technological learning resources.

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