LEARNING ELECTROCHEMISTRY USING FLIPPED CLASSROOM MODEL LEARNING MODULE

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Abstract

The use of flipped classroom model has been widely used as an effective teaching-learning. In this study, a learning module using flipped classroom model was developed and evaluated as a teaching tool in electrochemistry. Research and development composed of three phases were utilized. The first phase covered the development of the learning module. The second phase assessed the module's objectives, content, and technical qualities. The third phase evaluated the effectiveness of the module on students' performance. In this phase, a quasi-experimental method that utilized a pretest/posttest nonequivalent group design of freshmen civil engineering students were applied. Both groups experienced flipped classroom instruction. Contrariwise, only the experimental group used the learning module as supplementary material. Results revealed that the module's objectives were highly attainable, very clear, and very relevant. The module's content was also noted as very appropriate, very appealing, innovative, and was highly technical. The student's involvement index was *1.15,* indicating that the end-users can understand the concepts easily. The grade level is 13th, which is appropriate for the end-users, and the communication index is *0.01,* indicating that the words are simple and easy to understand. The independent *t*-test of posttest scores showed that there is a significant difference between the two groups (*t (40) =3.15, p-value=.003*). ANCOVA F (*1, 39) =9.904* and p=*.003* also revealed that the experimental group had better performance as compared to the control group. Both groups had medium gain after the intervention. Ergo, the use of the learning module using flipped classroom model is an effective tool in learning electrochemistry.

Keywords: *Learning Module, Electrochemistry, Flipped Classroom Model*

Introduction

Electrochemistry is one of the essential topics in chemistry because it deals with the production of electrical energy from chemical energy. Electrochemistry involves a large variety of concepts and problems such as redox reactions, standard electrode potentials, E^0; *Nernst* equation; electrochemical cells; and electrolysis. Consequently, strong mathematical skills are necessary to solve electrochemistry problems in which students proved hard to do (Tsaparlis & Malamou, 2014). Indeed, electrochemistry is one of the most challenging topics in chemistry for high school students and even at the university level (Akram et al., 2014, Treagust & Jong, 2002, and Lin *et al.,* 2003). This skill is needed to adequately understand electrochemical phenomena because of abstract concepts (Corriveau, 2011). In fact, both the high school and the college students and even preservice teachers manifest misconceptions and problem-solving difficulties (Corriveau, 2011). For example, the terms like 'ions,' 'atoms,' 'electrons,' 'equilibrium,' and 'delocalize' are least understood by the students. However, these terms are vital in learning electrochemistry. Corriveau (2011) also added that topics in voltaic and electrolytic cells are likewise difficult to understand because the process itself is invisible to the eye while the effect is observable. Henceforth, she recommended that solid knowledge of balancing redox half-reactions can lessen these difficulties.

The widespread use of the “flipped (or inverted) classroom model” has become a new pedagogical teaching strategy to improve teaching-learning in science education. The flipped classroom model may help establish in improving both the conceptual understanding and problem-solving skills of the students (Herreid & Schiller, 2013). Moreover, the flipped classroom instruction is viewed as a constructivist teaching approach. It effectively provides a learning environment in which students use their knowledge actively, construct their views about science, and develop critical thinking (Necor, 2019 and Felder *et al.,* 2015). Moreover, students has positive perceptions, lessons are easy to understand, enjoyable, timely, and engaging (Necor, 2019). In a flipped classroom, lectures and homework are done in reverse via short video lectures that are viewed by students outside the classroom at their own pacing, while in-class time is devoted to exercises, assessments, or discussions. Ruddick (2012) revealed that students using flipped classrooms have higher grades compared to a conventional lecture section in college chemistry. The students outperformed the standard lecture-based students, with higher final exam scores and overall success in class. Herreid & Schiller (2013) also added that flipped classroom is more interesting and students feel less humiliated. However, the potential of the flipped classroom can be maximized by the use of a teaching tool to guide students and teachers like learning modules.

The use of the learning module showed numerous advantages in teaching as a way of organizing a curriculum. A module can be administered to a single-use, small group, or large group of students that accept greater responsibility for learning (Sejpal, 2013). A module emphasizes the analysis and application of concepts and techniques and gives a particular style of ideas. It also provides active participation of students and helps the teacher extend more individualized instruction in school and at home (Guido, 2014). Modular instruction is advantageous to both students and instructors. The module may serve as a primary source of science content. It may also present specific views about the nature of scientific practices and how scientific knowledge developed. It may also serve as a primary influence on how teachers should teach science (Reiser *et al.,* 2003). With the use of modules, the progress of a student is assessed and the aspect of instruction routine was reduced - giving the teacher a chance to enjoy her contact with the students (Greager & Murray, 1991). The use of a learning module in a flipped classroom model has essentially helped in improving the performance of the students.

The essential benefits of the learning module are teaching-learning became more practical and the end-users work in their own environment and pacing. Hence, the learning module embedded in flipped classroom instruction must contain essential parts that aim to develop process skills and students’ critical thinking skills which include the objectives, content, and technical qualities. In this time of the pandemic, face-to-face teaching-learning is impossible to realize. Many schools around the world chose 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 such as the use of technology to address these challenges. It is believed that electrochemistry is one of the most challenging topics in chemistry, along with several algorithmic problems and misconceptions. Thus, the potential of flipped classroom instruction with the use of the learning module prompted the researcher to undertake this study. This is to respond to the continuous search for more meaningful and relevant science learning strategies that are beneficial to students and to teachers.

Objectives of the Study

This study aimed to develop a learning module in electrochemistry using the flipped classroom model as a teaching tool in electrochemistry. This study involved in designing a learning module in the following topics of electrochemistry. It also assessed the learning module in electrochemistry using a flipped classroom model (LME-FCM) in terms of Objectives, Content, and Technical Quality. Lastly, the effectiveness of the learning module was also evaluated based on students' performance in learning electrochemistry.

METHODOLOGY

Research Design

The study employed Research and Development method. Furthermore, a nonequivalent group design was used to determine the effectiveness of the Developed Learning Module in Electrochemistry using the Flipped Classroom Model (LME-FCM). The study comprised three phases. The first phase covered the development of the module as an instructional tool in learning electrochemistry. The second phase involved the assessment of the learning module in terms of objectives, content, and technical qualities. Additionally, the Student's Involvement Index, Grade Level, and Communication Index were also analyzed as part of the technical quality of the learning module. Lastly, the third phase of the study involved the effectiveness of LME-FCM on the performance of the students based on the gain scores.

Phase 1. Development of the Module

The topics included in the module are the following: basic concepts of redox, balancing redox reaction (acidic & basic solution); Galvanic/Electrolytic cell; standard reduction potential, E^o; thermodynamics of redox reactions; the effect of concentration of cell *emf* (*Nernst* equation); and applications of electrochemistry. These topics were incorporated into the learning module. Different short videos were downloaded online that are tailored to each topic. The module consists of nine (9) lessons. Each lesson has the following: Overview, Prerequisite Knowledge, Learning Objectives, Time Frame, Flipped Classroom Instruction, Key Concepts, Assessments, Summary, and Answer to Assessments.

Phase 2. Learning Module Qualities

The final draft of the module underwent a series of checking by the validators using a questionnaire. The evaluators include chemistry instructors who have been teaching college chemistry for more than five years. The evaluation form is composed of three qualities as Objectives Quality, Content Quality, and Technical Quality. The validators rated the module based on a Likert scale. Furthermore, the student's Involvement Index, Grade Level, and Communication Index (CI) following the procedures of Mocsir (2017) were also evaluated.

Phase 3. Effectiveness of the Learning Module

This phase of the study employed a quasi-experimental method that utilized a pretest/posttest nonequivalent group design. The independent variable is the learning module in electrochemistry using a flipped classroom model (LME-FCM), which is the intervention used in the study. The dependent variable is the student performance measured using posttest scores.

The Respondents

The first-year civil engineering students of Sultan Kudarat State University (SKSU), Isulan Campus, comprised the respondents. The selection of respondents was made using a purposive sampling technique whose criteria were appropriate for the research. The respondents were matched based on their scores in Lawson's Classroom Test of Scientific Reasoning (LCTSR, 2000). To be part of the respondents, a student must be at Transitional Operational (*TO*) and/or Formal Operational (*FO*) Reasoning. This matching was used to ensure that both respondents from both groups (experimental and control) are of equivalent or comparable capabilities. Some of the potential respondents were eliminated because of the lack of matching scores from the other group. The rest of the students who scored 3 or below were not considered as part of the sampling.

In the experimental group, each student was given a learning module whether he is part of the sampling or not. Students from both groups can access all the online videos in or outside the campus using their laptops or netbook or android mobile phones. All students in both groups were enrolled in an online classroom “easyclass," created by the researcher. The control group was exposed to the same method as the experimental group. Contrariwise, the control group has no access to the learning module.

Research Instruments

Phase 1. The instrument used in this phase is an evaluation form given to the chemistry instructors. In an evaluation form, a space was provided to write their comments and suggestions on the forms and face of the module. Their comments and suggestions were considered in the development of the learning module.

Phase 2. The instrument used in the second phase was the evaluation questionnaire in terms of the module's Objectives, Content, and Technical Qualities by the chemistry instructors. The survey has a corresponding score showing the extent of evaluators' agreement and disagreement on each indicator. These indicators are evaluative statements such as: Strongly Agree; Agree; Disagree; and Strongly Disagree and scored respectively 4, 3, 2, and 1. Student's Involvement Index, Grade Level, and Communication Index are obtained based on a standard evaluation tool.

Phase 3. The instruments used in this phase are the matching of respondents using LCTSR, pretest/posttest, and the effectiveness of LME-FCM. Only, the pretest/posttest scores are used to determine the effectiveness of the learning module in electrochemistry.

Intervention of the Study

A learning module in electrochemistry using flipped classroom model (LME-FCM) was used as an intervention in the experimental group only. A sample of the integration of flipped classrooms in the module, as shown in *Figure 1*. While a flipped classroom instruction was administered to the control group. Both groups have access to the online class. To help track the participation of each student, an assignment was posted in an online class that is anchored on the video/s. The videos were taken from reputable sources and pre-watched by the researcher before posting. The primary purpose of the assignment is to motivate students to watch the video before coming to class. By the end of the intervention, the sum of all of the quizzes, worksheets, and assignments accounted for 25%, 15%, and 10% of their total grade, respectively.

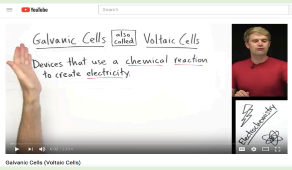
During the Class. The class started by soliciting questions from the students or by checking the Flipped Classroom Student Checklist (FCSC). The instructor was careful not to review the material in the video lesson again. The purpose of the discussion was to get feedback on what was not tackled or to provide more in-depth explanations. After this, students are given a formative assessment, such as a mixture of recitation, active learning, problem-solving, and activities. During the class, the students are not allowed to open their laptops or smart mobile phones during formative assessments. Students were encouraged to work with a partner, or by group depending on the tasks given. Across the groups, tests were completed on the same day and at the same time. Student's formative assessments, activities, and homework were checked and appropriately recorded.

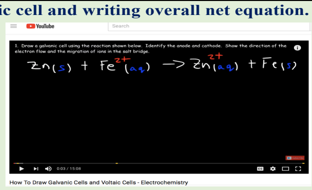
After the class. The class ended in both groups by gathering all formative assessments by the teacher and were checked immediately. The checked formative assessments were then returned to the students on the following class session. Moreover, the formative assessments were then recorded as part of their grading system. The students in both groups were informed on the videos to watch as well as their assignments in preparation for the next lesson. In addition, the learning modules were given to each student in the experimental group only.

In this lesson, you are going to use flipped classroom model instruction in learning Electrolytic and Galvanic cell. You will also learn how to draw, and label a Galvanic cell. Before coming to class, you need to watch the following videos to answer the assignment and worksheets.

FLIPPED CLASSROOM INSTRUCTION

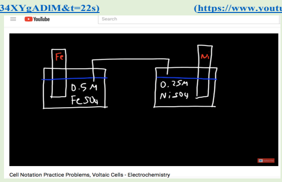
Please watch the following videos about Galvanic cell and writing overall net equation.





Video 7: Galvanic Cell (Assignment 4)
(https://www.youtube.com/watch?v=7b34XYgADlM&t=22s)

Video 8: How to draw Galvanic Cells?
(https://www.youtube.com/watch?v=vLCf4_NKjGU&t=35s)



Video 9: Net Overall Reaction (Assignment 5)
(https://www.youtube.com/watch?v=iWqUWwyPkSs&t=23s)

Learning Resources Outside School (*Outside Class*)	▪ Computer & Internet access ▪ Access to Easyclass ▪ Lists of videos to watch: **Video 7: Galvanic Cell** **(https://www.youtube.com/watch?v=7b34XYgADlM&t=22s)** **Video 8: How to Draw Galvanic Cell** **(https://www.youtube.com/watch?v=vLCf4_NKjGU&t=35s)** **Video 9: Net Overall Reaction** **(https://www.youtube.com/watch?v=iWqUWwyPkSs&t=23s)** ▪ Flash Drive or CD (for student without internet access at home) ▪ Paper and a writing materials ▪ Flipped Classroom Student Learning Checklist
Student Learning Activities at Home	▪ Study materials posted on the site following the instructions posted by the teacher. ▪ Collaborate with teachers through the forum of the platform. ▪ Collaborate with peers through the forum on the platform as well as creating groups on social networks or communication (Facebook, Skype, Google Drive) ▪ Prepare questions for the teachers ▪ Suggest other learning resources ▪ Answer Assignment

Figure 1. A sample lesson of the integration of the flipped classroom instruction.

RESULTS AND DISCUSSION

Phase 1. Face and Form Content of Learning Module

The first phase started by gathering comments and suggestions from chemistry instructors. Their constructive comments and suggestions were incorporated in the development and final draft of the learning module. The following are verbatim comments and suggestions raised by instructor A.

> *"Improve the preface of the learning module. Use a lighter color background so text can be read. Check the spacing between text and figures and headings. Make a separate guide for teachers on how to use LME-FCM. Write some tips for teachers to maximize learning can be useful. Be reminded that there is a limit to what you copy from online sources".*

The suggestions of the instructor A were incorporated in the final draft of the module. A preface and guide for teachers and students on how to use the module effectively were incorporated. Helpful tips for the learning module were also included. The researcher also revised the table by changing the font style and lighter background to make it readable. Similarly, all the pictures and figures copied from different sources were properly cited and acknowledged.

Phase 2. Assessment of the Learning Module

2.1. Objectives of Learning Module. The results of the evaluation show that the learning modules' objectives are highly attainable, very clear, and very relevant, as shown in Table 1. It illustrates that the content of the module are specific, observable behavior or skills, and action in small and discrete pieces. It further noted that the objectives lead students to mastery of the lesson and written from the learner's perspective yet achievable.

Table 1. Overall Chemistry Teacher Ratings on the Objectives of Learning Module in Electrochemistry using Flipped Classroom Model (LME-FCM)

Area	Mean Rating	Qualitative Interpretation
Attainability	3.45	Highly Attainable
Clarity	3.65	Very Clear
Relevance	3.65	Very Relevant

2.2. Content of Learning Module. The content of the learning module was evaluated by eleven (11) chemistry teachers in terms of appropriateness, appeal, innovativeness, and conformity with the standards. The evaluators strongly agreed that the module is very appropriate, very appealing, innovative, and strongly conforming, as shown in Table 2. The high ratings implied that the content of the learning module is suitable for the end-users.

Table 2. Overall Chemistry Instructor's Evaluation Rating on the Content of the Learning Module in Electrochemistry using Flipped Classroom Model (LME-FCM)

Area	Mean rating	Interpretation
Appropriateness	3.51	Very appropriate
Appeal	3.65	Very appealing
Innovativeness	3.34	Innovative
Conformity to Standards	3.64	Strongly conforming

2.3. Technical Quality. The learning modules' technical quality was also assessed by eleven (11) chemistry teachers. It involves a description of the design and layout of the module. Moreover, the technical quality conferred the activities that are well-linked to the objectives. The technical quality of the module also assessed the variation and authenticity of the activities or assessments. According to the chemistry instructors, the module is highly technical, with a composite mean score of 3.68. The evaluators agreed that the exercises in the module were interrelated to one another. They also agreed that the activities were varied at different levels of tasks and the end-users.

2.3.1. Student's Involvement Index. Results revealed that the student involvement index was found to be *1.15* indicating that the reader showed involvement in what he or she reads in the module. Romey (1965) cited that if the student's involvement index is higher than *1.00*, then the students, apart from reading, could perform activities and understand the mathematical manipulations presented in the module (or textbook).

2.3.2 Grade level. The learning module's grade level was calculated using the graph readability of Fry (1968). The grade level was determined by average syllables per 100 words in the first, middle, and last pages of the learning module. Extrapolating the number of syllables, it showed that the module was found to be in the 13^{th} grade (or First-year college) indicating that the module is intended for the end-users. According to Talisayon (1998), if the grade level of a learning material matches the grade level of the end-users, the writer has developed and presented the material in a manner easily understood by the end-users.

2.3.3. *Communication Index* refers to the readability of the module as perceived by the students. The communication index determines whether students can understand and follow the instructions in the module without difficulty using Talisayons' (1998) guidelines. The computed *CI* of the LME-FCM was found out to be 0.01. This value falls within the range of acceptable values of the communication index which is $0 \leq CI \leq 0.01$ set by Talisayon. It revealed that the students find the words in the learning module simple and easy to understand.

Phase 3. Effectiveness of Learning Module

Comparability of Posttest of Two Groups. The posttest scores were compared and analyzed using the independent *t*-test to determine if there is a significant difference in the achievement of the two groups after the intervention. Table 3 shows the descriptive statistics of the posttest score of the respondents on the electrochemistry achievement test. The experimental group obtained an average score of *26.95* during the posttest, while the control group scored *22.18* on average.

Table 3. Descriptive Statistics of Posttest Score on Electrochemistry Achievement Test

Group	N	Mean Pretest	SD	t	df	Sig (2-tailed)
Experimental Group	20	26.95	5.90	3.15	40	.003
Control Group	22	22.18	3.79			

Table 3 also showed the Independent Sample *t*-test of the scores. With a *p*-value of *.003* which is less than *.05* the results indicate that there is sufficient evidence to show that the posttest of the experimental group and control group significantly varies from one another.

To further analyze statistically the effect of the developed learning module in electrochemistry on the posttest scores alongside the effect of different interactions, an Analysis of Covariance [ANCOVA] was done where the dependent variable is the posttest scores, the independent variable is the treatment to the respondent and the pretest scores are considered the covariate. In performing ANCOVA, three assumptions were satisfied. These include: 1) the dependent variable (posttest score) and the covariate (pretest score) should be continuous; 2) the independent variable (treatment of the respondents) should be a categorical independent variable, and 3) the observations must be independent (Miller & Chapman, 2001). To check other assumptions, different tests must be performed.

Homogeneity of Variance

Table 4. Levene's Test of Equality of Error Variance

F	df1	df2	Sig.
2.726	1	40	.107

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
a. Design: Intercept + pretest + group

Table 4 shows Levene's test on the homogeneity of variance of the posttest scores of the respondents within the model wherein the treatment to the respondent is the independent variable and the pretest scores as the covariate. Since the *p*-value is *.107* which is greater than α=*.05*, the test of homogeneity of variance is not significant. There is no sufficient evidence to show that the variance of the posttest scores of the respondents from the experimental group and control group are different. The Design Intercept + Pretest + Group refers to the model used by Levene's test. It means that the variance used for this already involves the adjustment that the covariate [which is the pretest scores] brings.

Normality of the Residuals. Shapiro Wilk Test for Normality was calculated to check if the residuals of the model are normal, as shown in Table 5. Residuals refer to the difference between the expected score versus the observed score of the posttest.

Table 5. Shapiro Wilk Test for the Normality of Residuals

	Statistics	df	Sig.
Control	0.952	22	0.352
Experimental	0.952	20	0.402

Table 5 shows the Shapiro Wilk Test on the Normality of the Residuals by category. Since the *p*-value is *.352* for the control group and *.402* for the experimental group which are both greater than *α=.05*, the test of Normality of Residuals is not significant. There is no sufficient evidence to show that the residuals are normal.

Homoscedasticity. A residual plot of the post-test scores was determined to check the Homoscedasticity of the variable, as shown in Figure 2. The residual plot should be randomly spaced as possible to the horizontal axis for the variable to be considered homoscedastic. Since the residual plot shows the desired output, the variable is homoscedastic. It means that the assumption is of the same variance. It describes that the relationship between the independent variables and the dependent variable (post-test scores) is the same across all values of the independent variables (treatment of the respondents).

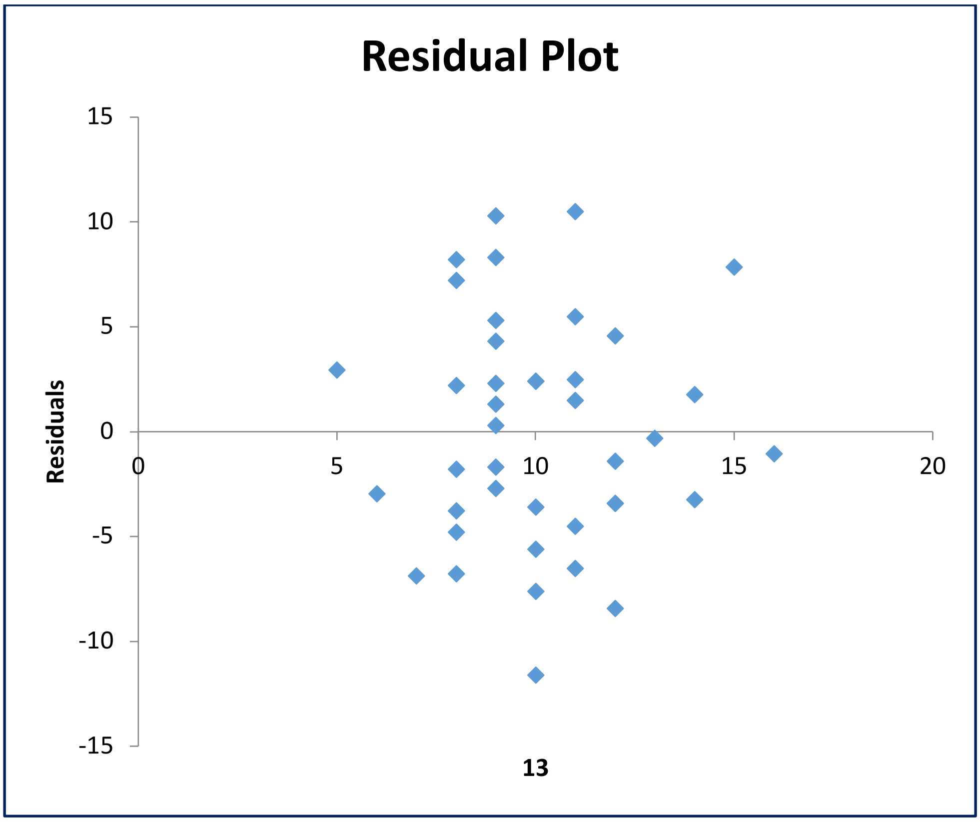


Figure 2. The Homoscedasticity Residual Plot of the Post-test Scores

Performing the test of ANCOVA. Since the assumptions were satisfied, the Analysis of Covariance [ANCOVA] was performed. Table 7 shows the ANCOVA analysis, which further tests both the posttest scores of two groups with pretest scores as the covariate. The dependent variable, group treatment, explains *16.60%* (Adjusted R^2 = *.166*) of variation in the regression model. Moreover, Table 7 revealed that the different interventions [controlled and experimental] were statistically significantly different having adjusted for the covariate [Pretest score] with F (*1, 39*) = *9.904, p = .003*.

Table 7. Analysis of Covariance (ANCOVA) Results of the Posttest Performance of Students with their Pretest Scores as Covariate

Source	Type III Sum of Squares	df	Mean square	F	Sig (p-value)	Observed Power
Corrected Model	247.655[a]	2	123.828	5.069	.011	.206
Intercept	1461.569	1	1461.569	59.828	.000	.605
Pretest	9.473	1	9.473	.388	.537	.010
Group	**241.939**	**1**	**241.939**	**9.904**	**.003 S**	**.203**
Error	952.749	38	24.429			
Total	26313	42				
Corrected Total	1200.405	41				

R^2 = .206 (Adjusted R^2 = .166); p<.05; S (significant)
Dependent Variable: post-test

It disclosed that there was a significant difference between the adjusted posttest mean scores of the experimental and control groups after controlling the influence that their pretest scores may have on their posttest scores. Moreover, it means that the experimental group performed better than the control group.

Table 8. Estimates of Posttest Score on Electrochemistry Achievement Test evaluated in the covariate

Group	N	Mean Posttest	SD	95% Confidence Interval	
				Lower Bound	Upper Bound
Experimental Group	20	26.97	1.11	24.735	29. 209
Control Group	22	22.16	1.05	20. 029	24.294

*Covariates appearing in the model are evaluated at Pretest = *10.143*

Table 8 shows the adjusted Estimates of the Posttest Scores on Electrochemistry Achievement Test evaluated in pretest = *10.143*. Upon adjusting the mean scores, the experimental group performed better than those in the control group in learning electrochemistry. These results can be supported by some of the students' statements shown in their journals.

Student 20, Experimental Group

"The LME-FCM helps the students to develop study habits and independency. By this, learning somehow have to depend on themselves and understand more about certain topics. The method helps the learners to understand calculations in electrochemistry without the aid of traditional teaching method, which is a new type of learning style."

Student E#20 shown manifests that the module helped him enhance his understanding of electrochemistry. He also reiterated that he enjoyed learning and improved their critical thinking and problem-solving. It can be noted that students E#20 and E#10 believed that the module developed their independent learning. Student E#10 added further that the module also improved his time management.

Student 10, Experimental Group

"It helped me understand certain topics independently with the aid of given modules (hard copy, linked video tutorial, etc.). it helped me manage my study time. It's my first time to encounter this kind of method and at first, I was overwhelmed and had to adjust but it's still a good approach."

CONCLUSION

The learning module consists of nine lessons that covered the essential topics in electrochemistry for engineering. Each lesson was composed of an overview, objectives, key concepts, flipped classroom instruction, assessments, summary, and references. The learning module was highly attainable, very clear, and very relevant in terms of the objectives quality. The module was very appropriate, very appealing, innovative, and strongly conforming with the standards in terms of the content, and lastly, the module was highly technical. The modules' involvement index was found to be *1.15* and matches to grade level of the end-users that is 13th grade. The communication index (CI) of the module was found to be *0.01*. The experimental group performed better compared to the control group in terms of the mean score after the intervention. The use of the learning module was found to be effective in improving the performance in electrochemistry. Indeed, chemistry teachers may use the developed learning module using the flipped classroom model in teaching electrochemistry. Flipping the classroom might increase engagement in the classroom, particularly in learning electrochemistry. Teachers may use this study to guide them on how to implement an efficient and productive teaching-learning in electrochemistry using a flipped classroom model. The use of the learning module in this study may serve as a benchmark for future studies if teachers may decide to adopt the Flipped Classroom Instruction in other topics. The flipped classroom can be a strategy that creates more time and space for meaningful learning activities. Hence, teachers need to design their classroom activities to move away from the conventional methods of acquiring knowledge through the use of technology.

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