International Journal on
"Technical and Physical Problems of Engineering"
(IJTPE)
Published by International Organization of IOTPE

ISSN 2077-3528
IJTPE Journal
www.iotpe.com
ijtpe@iotpe.com

June 2024	Issue 59	Volume 16	Number 2	Pages 185-194

INFLUENCE OF SIMULATION IN FLIPPED TEACHING MODEL ON LEARNERS PERFORMANCE IN ELECTROLYSIS INSTRUCTION

A. El Kasri [1] M. Abid [2] A. Lebkiri [1]

1. Advanced Materials and Process Engineering Laboratory (LMAGP), Faculty of Sciences, IbnTofail University, Kenitra, Morocco, amina.elkasri@uit.ac.ma, ahmed.lebkiri@uit.ac.ma
2. Laboratory of Scientific Research and Pedagogical Innovation, Regional Center for Education and Training Professions, Rabat, Morocco, profabidmed@gmail.com

Abstract- The paper investigates the effect of the proposed course map and its three-phase implementation, which is supported by a flipped classroom method and asynchronous lectures, on Moroccan pupils' learning electrolysis concepts. As part of a quasi-experimental design, pre- and post-tests were performed before and after the pedagogical interventions. The sample consists of two groups of pupils: experimental (34) and control (31). The experimental group employed the flipped classroom method to learn the lesson subjects, whereas the control group used traditional face-to-face teaching method. To describe and compare the obtained data, descriptive and inferential statistics were utilized with the appropriate software. The obtained results show that the experimental group performed the control group significantly. Indeed, the post-test results indicate a significant difference in mastery of new learning related to the electrolysis course between the experimental group (mean rank=38.76) and control group (mean rank=26.68) groups, with the EG pupils excelling the CG ones. Summative test results show a significant difference in pupil performance between experimental group pupils (mean rank=38.72) and control group (mean rank=21.11). This study concludes that the suggested flipped classroom method has direct and favorable effects in learning, retention and effective assimilation of electrochemical concept and principals.

Keywords: Pupils, Flipped Classroom, Chemistry, Redox, High School, Performance.

1. INTRODUCTION

The flipped classroom instructional approach has garnered substantial attention as a pioneering method for teaching and learning, particularly noted for its impact on science education [1]. This innovative methodology, characterized by the inversion of traditional classroom activities, holds promise in enhancing students' comprehension and retention of intricate concepts. The primary aim of integrating the Flipped Classroom model in science education is to foster active engagement and profound understanding among students. By reshaping the conventional structure, where in-class lectures are supplemented with at-home exercises, learners are provided with preparatory materials, such as pre-recorded video lectures and readings, ahead of class. This equips them to grasp foundational concepts and underlying principles at an individualized pace. Classroom time is thus utilized for interactive activities, collaborative problem-solving, and discourse, allowing pupils to apply their knowledge, seek clarification, and receive personalized guidance from educators.

Empirical research has demonstrated encouraging outcomes in terms of student achievement and involvement when applying the Flipped Classroom approach to teaching chemistry's principles. For example, [2] explored the influence of this approach on students' grasp of Redox reactions, revealing higher performance levels and enhanced enthusiasm for learning chemistry compared to traditional methods. In spite of its prominence in technology-integrated learning, the empirical substantiation for the flipped classroom's efficacy remains limited. Nonetheless, case studies indicate its positive impact on STEM subjects, particularly in the Science, Technology, Engineering, and Mathematics domains [3].

Recent findings, such as [4] study examining first-year students' readiness for the flipped classroom and [5] analysis of its impact on motivation and academic achievement, carry our interest to this research. Moreover, [6] emphasize the need for tailored designs, stressing that thoughtful planning significantly influences outcomes. In light of the evolving educational landscape, these contributions elucidate the potential advantages of the flipped classroom and offer insights for effective implementation.

On the other hand, traditional lectures provide few opportunities for pupils to interact with lecturers and ask questions, and the content cannot be adjusted to match the needs of different pupils [7]. Pupils find it difficult to focus during lectures [8]. But interactive tutorials might be problematic if they are not designed properly consist solely of informal discussion on readings or lectures: There could be a proclivity for the same pupils to speak up/silence, low quality due to a lack of preparation, as well as inadequate engagement and talents development is hindered due to a lack of variety in learning activities.

Registered: 230924 Article Info: 1796 Accepted: 240524
Reserved: 240118 Available: 240630

However, comprehensive investigation and in-depth research are imperative to establish the flipped classroom effect on pedagogical approaches. Despite, the favorable outcomes, implementing flipped classroom techniques in science education, specifically chemistry, presents certain challenges. Significantly, the demand for technological infrastructure and resources poses a hurdle, especially in contexts with limited internet access and appropriate devices. Additionally, educators must acquire new skills to create engaging preparatory materials, facilitate active learning experiences, and offer personalized support.

In the Morocco context, "GENIE" program, introduced in 2006 by the Ministry of Education, marked the start of the digital revolution of the educational landscape in Morocco, but the Covid-19 health crisis gave it a tremendous boost. In fact, the Moroccan Ministry of Education adopted alternating face-to-face and distance learning as the new pedagogical strategy for the 2020-2021 academic year in response to the pandemic situation (Ministerial Note 039x20), developing materials on its official "TelmidTICE" platform or airing them on national television to reach as many pupils as possible, especially those without internet access.

However, some writers [9] and the thematic report of the Higher Council for Education, Training and Scientific Research [10] have criticized this experience, citing significant challenges and restrictions with distance learning. Through two strategic objectives, the Ministry's digital plan for 2030 is to establish a school that is forward-thinking, outfitted, linked, and integrated into the knowledge society. These aim to build students' Information and communication Technology (ICT) abilities and integrate ICT into the curriculum from the start. As part of the implementation of Framework Law 51-17 [11] several goals are stated. As a result, it will be possible to include digital technology into the updated curricula for schools as well as to keep schools equipped and connected, train instructors, and create new content and uses through annual action plans at the federal, provincial, regional, and local levels. A platform (e-takwinetanmia) for digital classroom pilot has been introduced this academic year, with plans to expand it if the experiment is successful.

The purpose of this study is to design and investigate the effect of a proposed planning and managing chemistry course in various flipped classroom applied phases on pupils' problem-solving abilities related to redox concepts (electrolysis). The flipped classroom method is supported by the Learning Management System (LMS) may increase students' interest and performance in chemical concepts to obtain better academic achievements. The main research questions as follow:

- Does the design and implementation chemistry course with flipped classroom delivered via the LMS significantly exceed the conventional face-to-face way of instruction in terms of improving learners' understanding of chemistry?

2. LITERATURE REVIEW

2.1. Flipped Classrooms

Instruction moves from the group learning space to the individual learning space, and the resulting group learning space is transformed into a dynamic, interactive learning environment where the teacher supports students as they apply concepts and engage creatively in the subject matter [12]. This definition is illustrated in Figure 1, where we show the flipped class's method derives from the inversion of Bloom's revised taxonomy low learning levels in the traditional approach based on the workspace [13].

The "flipped classroom" strategy, also called as the "inverted classroom" or "reverse instruction," is a way of using technology to "flip" or "reverse" what is typically done in class with what is typically done as homework, supporting educational material for pupils that can be accessed online. The fundamental idea behind the flipped classroom is to move the "delivery" of material outside of scheduled class time while allowing pupils to engage in collaborative and interactive activities during scheduled class time that are related to the material.

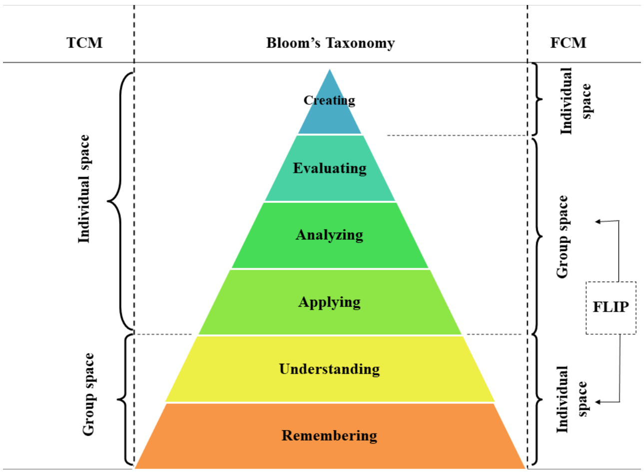

Figure 1. Traditional (TCM) and Flipped Classroom (FCM) Framework of Bloom's Revised Taxonomy [13]

2.2. Practices for Teaching Online

Teaching online has become increasingly prevalent in today's educational landscape, necessitating the implementation of effective practices to ensure quality and engagement in virtual learning environments. Educators are faced with the challenge of adapting their teaching methods to suit the digital realm while maintaining high standards of instruction. Several research studies have shed light on best practices for teaching online that promote active learning and student success. In the online education domain, several essential practices have emerged to enhance teaching effectiveness and foster meaningful learning experiences.

One such practice is the establishment of a strong online presence, as emphasized by [14]. Engaging with pupils through regular interactions and providing timely feedback contributes to a supportive and engaging learning environment [15], promoting a sense of instructor availability and active involvement in the virtual classroom. Furthermore, leveraging technology appropriately plays a critical role in successful online teaching. [16] research highlights the significance of incorporating multimedia elements, such as videos and interactive simulations, to facilitate better comprehension and engagement among students. By utilizing these technological tools strategically, educators can enhance the overall online learning experience. Moreover, well-designed course structures are equally vital for effective online teaching. [14] stress the importance of clear learning objectives and organized content to guide pupils systematically through their learning journey. Ensuring intuitive navigation and a logical sequence of topics contributes to a seamless learning experience for students.

Additionally, fostering student interaction and collaboration is key to building a sense of community in the online learning environment. [17] advocate for the use of various collaborative tools, including virtual group projects and peer discussions, to encourage active participation and knowledge-sharing among students. Lastly, regular assessments and timely feedback are essential components of successful online instruction. [13] research emphasize the significance of formative assessments in providing valuable insights into student progress and identifying areas for improvement. By embracing these evidence-based practices, educators can create robust and engaging online learning environments that support students' academic growth and cultivate a positive and successful virtual learning experience. Through intentional implementation of these practices, instructors can make a significant impact on the effectiveness and outcomes of online education.

3. MATERIALS AND METHODS

3.1. Design an Online Flipped Classroom Lesson

3.1.1. Flipped Learning Lesson Planning

The following five stages are included in electrolysis's online lesson planning based on the flipped classroom approach that is the subject of this study:

- Stage1: Write a list of clear, measurable learning objectives for our lesson. Based on the official Moroccan instructions for 2nd year baccalaureate physics and chemistry, we draw up a list of clear, measurable learning objectives for the electrolysis lesson, indicating what pupils should be able to do once the lesson is over.
- Stage 2: Divide the learning objectives into "Basic" objectives and "Advanced" objectives. This stage defines what pupils should be able to perform before, during, and after class, according to the zone of proximal development approach (ZDP) [18]. To accomplish this, we establish a line between the before-class and during-class objectives according to Bloom's revised taxonomy. Taking into consideration the items on our list of learning objectives, which moment on our list of learning objectives is the lower task (Basic learning objectives) we can reasonably expect a pupil to complete before class, thanks to an independent self-learning structure, and which moment on our list of learning objectives is the higher task (Advanced learning objectives) we expect pupils to tackle thanks to their active work in class?
- Stage 3: Design and construct the pre-class activity around the basic objectives. To proceed, pupils are required to pass a diagnostic exam on the prerequisite knowledge needed to understand the redox and Daniel cell concepts. This is followed by an overview that gives a quick introduction to the lesson on "electrolysis" by connecting it to previously learned material. The 'Basic' and 'Advanced' 'Learning Objectives' are displayed to illustrate the expectations of pupils. Following that, a list of "Learning Resources" offers a suggested selection of text (who pupils be expected to complete in the course), video (recorded asynchronous lectures), and multimedia resources (online chemistry educational videos from various websites, mobile application, simulations, and interactive software's) to aid learners in effectively interacting with their basic learning objectives (Remembering and Understanding). Learners can share and exchange knowledge with each other in a teacher-moderated an asynchronous discussion forum (peer-to peer and pupil to teacher interactions). Training exercises for the basic objectives are also planned, and learners are invited to do them after reading and watching the aforementioned resources.
- Stage 4: Design of the in-class/group space activity around the advanced objectives. The components in the middle of revised Bloom's Taxonomy (Apply, Analyze and Evaluation) are typically used in class activities. Active learning should be incorporated into these activities: "anything that involves pupils in doing things and thinking about what they are doing" [19]. We select in-class activities (formative assessments) in such a way that they consolidate the basic objectives related to pre-class work, and are consistent with the course's advanced learning objectives, and facilitate students' development of desired skills and knowledge. The selection of main classroom activities considers one formative assessment per lesson objective, adheres to a progressive scale of difficulty, and avoids redundant elements that do not contribute significantly to the learning objectives (e.g., quizzes, examinations of high difficulty points, exercises and problems).
- Stage 5: Design and construct any post-class activities. Create activities that take place after the group space/classroom activities are completed. Bloom's taxonomy components (create) are commonly utilized for post-class activities. Following the in-class practice, we identify advanced learning objectives that require more attention. Activities are identified (problems to solve, real-life applications of electrolysis to research, models, documentation link, final group project and summative assessment) that enable continual engagement with advanced learning objectives within the time it would take an average learner to accomplish each activity.

3.1.2. Managing Flipped Learning Lesson

Effectively managing a flipped classroom requires an integrated approach encompassing various work spaces to optimize the learning experience, as shown in Figure 2.

➢ Pre-classroom preparation: Pupils are required to complete individually a diagnostic test of the prerequisites for the concepts of a spontaneous transformations lesson in the out-of-class environment after logging in with their personal accounts to the "MySchool" platform(https://myschool.anappios.com/). Following that, they are directed to read pre-reading materials from textbooks and curricula and view video sequences of the "electrolysis" course and simulations of electrolysis operating, in which key themes, definitions, and instructive examples are addressed. Formative assessments (quizzes and exercises) have been integrated into these resources, which learners are asked to complete and submit. The teacher will then create and manage an online discussion forum to give pupils a place to interact with the pre-reading material and video contents. Through the sharing of queries and points of view, this forum encourages peer-to-peer interaction, teamwork in study, and the pursuit of clarification.

➢ In-classroom facilitation: Once within the classroom environment, an interactive blend of activities facilitates deeper understanding. A succinct review of the pre-reading materials and video content is conducted, reinforcing comprehension and addressing queries raised in the online forum and the observed difficulties in the pre-class performances and formative assessment. Active participation is cultivated through interactive group activities, wherein learners collaborate in experiments centered on electrolysis. Detailed instructions guide pupils through each step of these hands-on experiments, promoting hands-on engagement. Collaborative problem-solving sessions are introduced, presenting intricate challenges linked to electrolysis for groups to collectively resolve. This approach nurtures teamwork, critical thinking, and the practical application of theoretical concepts. Guided discussions transition the focus to real-world applications of electrolysis in industries. Here, pupils are encouraged to bridge theoretical understanding with real-world scenarios, fostering a holistic grasp of the subject matter.

➢ Post-classroom enrichment: Following the in-class activities, a range of activities and assessments contribute to the consolidation and extension of learning outcomes. Supplementary resources such as articles, videos, and links to online simulations are shared to encourage further exploration and self-directed learning. To foster individual reflection, pupils are assigned a task to summarize key takeaways, identify challenges encountered, articulate newfound insights, and outline areas for improvement. This reflective exercise nurtures metacognition and self-awareness. Subsequently, a comprehensive assessment is administered to gauge pupils' comprehension and application of electrolysis principles to real-world scenarios. To conclude the flipped lesson, a final online discussion is orchestrated. This forum addresses any lingering questions, provides closure to the topic, and strategically connects the acquired knowledge to subsequent lessons or potential applications.

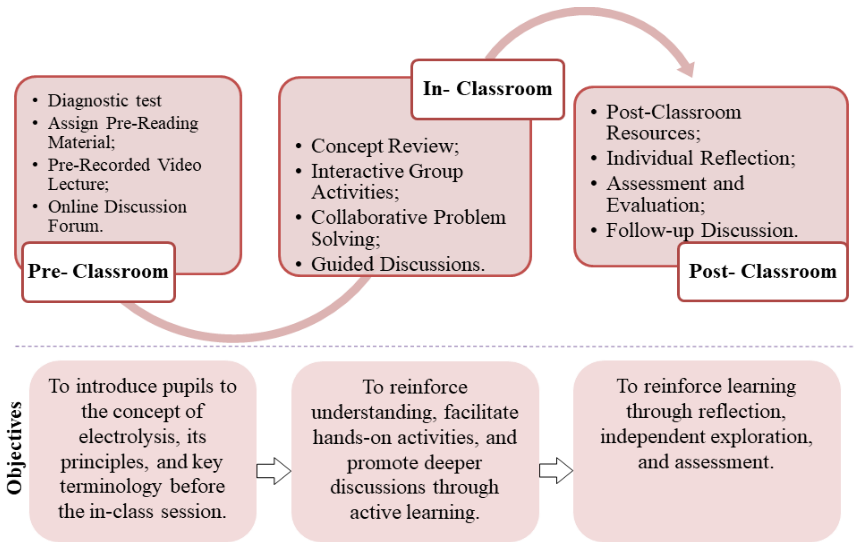

Figure 2. Designing the Research Framework for three phases Flipped Lesson Management

3.1.3. Educational Platform

In the context of the educational framework, the specialized "MySchool" platform (https://myschool.anappios.com/) was developed to facilitate an effective electrolysis lesson using the Moodle Learning Management System. This platform featured a dedicated control panel comprising key elements designed to create an engaging learning experience. The platform began with the integration of "Official Pedagogical Objectives" aligned meticulously with the curriculum, outlining essential learning outcomes for the electrolysis lesson. To assess pupils' initial understanding, a "Pre-test" was administered, consisting of five problem-solving questions, providing insights into areas requiring further attention.

The lesson contents encompassed a comprehensive "Study of Electrolysis," covering relevant concepts and formulae. A structured "Video course" by an expert professor was presented in three parts, facilitating manageable comprehension.

Real-life experiments were showcased through "Experimental Videos," categorized into microscopic and macroscopic scales. The lesson culminated with a "Post-test" of seven questions to evaluate pupil's progress. By thoughtfully integrating these components, the "MySchool" platform provided an interactive and comprehensive approach, enhancing students' understanding and engagement with electrolysis concepts.

3.2. Methods

3.2.1. Participants

The study included a total of 65 pupils in their second year of the baccalaureate program in the second semester of the academic year 2022-2023, majoring in Physics and Chemistry. Among them, 34 pupils were assigned to the experimental group, while 31 pupils formed the control group.

3.2.2. Methodology

In this study, a quasi-experimental design was used to examine the effectiveness of our lesson supported by the flipped classroom method. A pretest, posttest and summative test were deployed for both control and experimental groups towards the end of the 2022/2023 school year.

- Experimental group: The experimental group (EG) received instruction using the flipped classroom pedagogy. Each student in this group was provided with an individual account on the "MySchool" platform, which allowed them to access the lesson materials, including video lectures, experimental videos, and other relevant resources. They were also able to complete the required tasks, such as the pre-test and post-test, remotely at home. In the classroom, the pupils in the experimental group engaged in exercises and applications that were specifically designed to reinforce the concepts covered in the lesson. The teacher provided supervision and guidance during these activities. The pupils' responses and solutions to the exercises were recorded on paper for later analysis.
- Control group: The control group (CG), on the other hand, received instruction using conventional face-to-face teaching method in a traditional classroom setting. The lessons were delivered face-to-face by the teacher, and the pupils' learning activities.
- Assessments: Assessments were performed on both the experimental and control groups to measure learning outcomes. The assessments, which were given in the form of a continuous control, covered two types of levels skills: low (basic learning objectives) and high (advanced learning objectives). The post-test low-level skills consist of determining the chemical species in solution and the redox couples involved in the electrolysis in question, whereas the high-level skills measure pupils' ability to write the balance equation for the electrolysis of an aqueous solution of NaCl and calculate the value of the maximum quantity of hypochlorite ions (ClO-) that the device can supply over a period of t= 1.0 hour of operation. The low-level skills in the sum-test consist of determining the description of the electrolysis in question (anode, cathode, direction of current and electron, species), whereas the high-level skills assess pupils' abilities to write the balance equation of the electrolysis, find the mass (m) of magnesium deposited over the time t, and calculate the volume V of chlorine released under the conditions of the experiment over t. The experimental group took the pre and post-tests remotely via the "MySchool" platform, while the control group took the tests face-to-face manner. The specified total time for the electrolysis lesson is 150 minutes. Table 1 illustrates the time gained by flipped learning (FCM) compared to the traditional face-to-face method (TCM).

Table 1. The time allocation for electrolysis lesson using both TCM and FCM methods

Tasking	Timing	
	TCM	FCM
Diagnostic assessment	20 min	20 min
Lesson and formative assessment	60 min (conventional)	60 min (video/text/quizzes)
Experiences	10 min (Theoretically)	10 min (Video)
Application activities (exercises and problems)	60 min	120 min
Summative assessment	40 min	40min
Total	190min	250 min

3.2.3 Data Collection and Analyses

Data collection involved the collection of pre-test, post-test and summative test scores for both groups. Descriptive statistics were used to analyze and compare the performance of the experimental and control groups. Statistical analysis, including inferential test (Mann-Whitney U-test), conducted to determine the significance of any observed differences between the two groups. The study adhered to ethical guidelines and obtained appropriate consent from the participants or their guardians. Confidentiality and privacy of the participants' data were maintained throughout the study.

4. RESULTS AND DISCUSSION

4.1. Results and Interpretation

Our main goal is to investigate the effect of our suggested electrolysis course map and its management, supported by three phases of flipped classroom method (FCM), on the performance of pupils. To that purpose, we first examined and compared the pre-test results to ensure that the experimental and control groups were homogeneous. Second, we studied and compared the obtained post-test and sum-test results to reach conclusions.

4.1.1. Describing Pre, Post and Summative-Tests Results

Table 2 presents the outcomes of the descriptive analysis in terms of mean and standard deviation for the three assessments conducted on both the experimental and control groups. For the pre-test phase, our study involved administering pre-test assessments to each participant in the experimental groups (n = 34). These assessments were administered individually through pupil's mail and an online access code via the educational platform

"MySchool". On the other hand, the control group ($n = 31$) undertook the pre-test within the classroom setting. Observing Table 2, it is evident that the mean score for problem-solving (spontaneous transformations-cells) among the experimental group was (8.70) with a standard deviation (4.12), in which the averages scores for lower and higher levels skills are (8.50) and (8.93), respectively.

Table 2. Descriptive results according to group and level skills

Tests	Pre-test		Post-test		Sum-test	
Groups	CG	EG	CG	EG	CG	EG
N	34	31	34	31	34	31
Mean	9.67	8.70	9.49	13.22	11.25	16.87
SD	4.23	4.12	3.57	5.74	4.83	4.71
Mean lower level skills	10.20	8.50	8.60	14.00	12.20	18.20
Mean higher level skills	9.73	8.93	9.50	12.40	10.30	15.06

The control group, in comparison, displayed a slightly higher mean score of (9.67) with a standard deviation of (4.23), while the averages scores for lower and higher-level skills are (10.20) and (9.73), respectively. These initial findings underscore that, prior to any intervention or treatment; the control group performed slightly better than the experimental group in the pre-test. Therefore, statistical tests will be used to compare the two groups' equivalency.

Furthermore, Table 2 provides insights into the post-test outcomes for mean scores in problem-solving (electrolysis activity) for both the experimental and control groups. The experimental group obtained a mean score of (13.22) with a standard deviation of (5.74) and averages for lower and higher-level skills of (14.00) and (12.40), respectively, while the control group received a mean score of (9.49) with a standard deviation of (3.57) and averages scores for lower and higher-level skills of (8.60) and (9.50), respectively. An initial reading of the post-test results show disparities in performance between the two groups after implementation of the experimental intervention. To validate these descriptive analysis results, we will use inferential analysis.

Additionally, the final exam serves as a comprehensive evaluation conducted at the conclusion of the study to assess overall learning outcomes and participant performance. In this context, the exam took place two weeks subsequent to the post-test phase, thereby enabling the assessment of the enduring effects of employing the flipped classroom method. With regard to the summative assessment, it should be noted that the absence of five pupils resulted in a total participant count of 60 learners, comprising 32 in the experimental group and 28 in the control group, as outlined in Table 2. The averages scores achieved by pupils in both experimental and control groups are elaborated upon. Specifically, the experimental group attained an average score of (16.87) with a standard deviation (4.71) and means for lower and higher-level skills of (18.20) and (15.06), respectively, while the control group obtained a mean score of (11.25) with a standard deviation (4.83), in which the averages for lower and higher levels skills are (12.20) and (10.30), respectively.

Noteworthy is the considerable variance in mean scores observed between the two cohorts. Evidently, the experimental group demonstrated a markedly superior mean score of (16.87) in the final exam, presenting a substantially contrast to the control group's notably lower mean of (11.25). These findings underscore the enduring and positive effect of the experimental intervention on learners' academic performance. To confirm the results of the descriptive analysis, we will use an inferential analysis using the Mann-Whitney test to verify the statistical significance of the results between the two groups.

4.1.2. Distribution of Pupils' Performances in Tests Based on the Teaching Utilized Method

The main purpose is to study the effect of the flipped classroom method (FCM) on the teaching and learning of chemistry by second-year baccalaureate pupils. In fact, we first examined and compared the results of the pre-test and the post-test, as well as the final tests, according to the method adopted for solving chemical problems involving redox concepts. All analyses were performed using SPSS Statistics 23. The results showed a non-normal distribution for both the control (*CG*) and experimental (*EG*) groups, as presented in Table 3. The Kolmogorov-Smirnov test was used to determine the normality of the data, considering that the number of samples is greater than 50. Obtained Data is considered to have a normal distribution if the Kolmogorov-Smirnov value is greater than the significance value of 0.05.

As shown in Table 3, the p-values for the pre-test, post-test and sum-test results were all smaller than 0.05 for both the control group (0.002; <0.001; 0.029) and the experimental group (0.053; 0.006; <0.001) respectively, indicating that the corresponding data does not follow a normal distribution. The Mann-Whitney U test was therefore carried out for the results of the three tests.

Table 3. Kolmogorov-Smirnov normality of Tests according to the groups

Groups		*EG*	*CG*
Pre-test	Stat.	0.149	0.205
	df	34	31
	Sig.	0.053	0.002
Post-test	Stat.	0.182	0.259
	df	34	31
	Sig.	0.006	0.000
Sum-test	Stat.	0.339	0.166
	df	34	31
	Sig.	0.000	0.029

The findings Mann-Whitney U-test results of the obtained data from the pre-test, post-test and sum-test are presented in Table 4. The mean ranks assigned to the experimental and control groups were 31 and 35.19 respectively for the pre-test assessment. The associated significance level of 0.349, determined at U(MW) with a value of 459, is notably higher than the predetermined alpha threshold of 0.05. This outcome implies that there was no statistically significant distinction in the pre-test within both the experimental and control groups. As a result, the initial null hypothesis was upheld.

Furthermore, Table 4 underscores that the mean ranks observed in the experimental group exhibit statistically significant elevation in both the post-test and sum-test (38.76 and 26.68) evaluations when compared to those in the control group (26.68 and 21.11), respectively. The corresponding significance levels are denoted as 0.008 and <0.001 p values, each linked to U(MW) values of 331 and 185, respectively. These significance levels are appreciably lower than the predefined alpha value of 0.05. This distinction indicates that learners who engaged with the proposed lesson using FCM method achieved markedly superior academic outcomes in contrast to their counterparts who were exposed to the TCM face-to-face approach. Consequently, the initial null hypothesis was rejected, and the first hypothesis, which posits a favorable influence of the flipped teaching method on the comprehension of electrolysis concepts, was substantiated.

Table 4. Mann-Whitney U-test results for the three tests according to the teaching methods used

Groups		EG	CG
Methods		FCM	TCM
Pre-test	*N*	34	31
	Mean rank	31.00	35.19
	U Mann-Whitney	459.000	
	W Wilcoxon	1054.000	
	Z	–0.936	
	Asy. sig	0.349	
Post-test	*N*	34	31
	Mean rank	38.76	26.68
	U Mann-Whitney	331.000	
	W Wilcoxon	827.000	
	Z	–2.633	
	Asy. sig	0.008	
Sum-test	*N*	34	31
	Mean rank	38.72	21.11
	U Mann-Whitney	185.000	
	W Wilcoxon	591.000	
	Z	–4.074	
	Asy. sig	0.000	

4.2. Discussion

This study investigated the effect of a proposed course map and its implementation supported by three phases of flipped classroom method, using an asynchronous learning management system (LMS), on pupils' performance and learning outcomes in electrolysis lesson of 2nd year baccalaureate learners. The findings from the post-test show a substantial difference in mastery of new learning related to the electrolysis lesson between *EG* (mean rank=38.76) and *CG* (mean rank=26.68) groups, in favor of the *EG* pupils. This difference is apparent in both obtained means scores of low and high levels of skills (Table 2). We can, therefore, conclude that the suggested FCM method has direct and favorable effects.

The course map and its management, assigned to the experimental group, are based on learning through individual work, self-learning and a student-centered pedagogical approach using an asynchronous learning management system (LMS) in the pre-class phase, followed by collaborative efforts, instructor-led learning, and knowledge sharing in the classroom space, and finally in-depth assimilation and research in the post-class phases.

Several authors state that a well-designed flipped classroom has been shown to promote learning outcomes such as superior learning achievement in revised Bloom's taxonomy, increased behavioral engagement, enhanced peer-to-peer interactions, and overall learning experience [20, 21, 22]. Indeed, based on Bloom's revised taxonomy and Vygotsky's theory of the Zone of Proximal Development:

- The dividing of learning objectives into basic objectives (lower levels of skill learning) from which the learner can learn independently and advanced objectives (higher levels of skill learning) from which the learner needs assistance and helps to enhance their self-learning, working in a group, and problem-solving skills;
- The significance of clearly defined learning objectives; Well-organized information in guiding students methodically through their learning education [23].

Additionally, the Platform provides pupils the chance to revisit the course material (recorded videos, simulations) multiple times, download course documents and take part in the discussion forum, all of which increase learner engagement, motivation and self-paced learning [24]. Notably, the EG group received 120 minutes for enrichment activities compared to the CG group's just 60 minutes, providing the experimental group with additional opportunities for both peer-to-peer exchanges/communication and resources interactions, as well as problem-solving situations (Table 1).

The summative test results taken 15 days following the post-test reveal a significant difference in pupils' performance in favor the EG pupils (mean rank=38.72) CG compared to CG (mean rank=21.11). However, the sum-test results of both groups improved noticeably when compared to the post-test. In reality, the EG scored a sum-test mean score of 16.87 versus 13.22 for the post-test, while the *CG* received a sum-test average mark of 11.25 versus 9.49 for the post-test. However, in terms of averages earned at the low and high skill levels, EG pupils performed significantly better than *CG* ones.

There was, however, a substantial difference between the two groups in favor of the experimental one who had been taught electrolysis using the novel approach. These findings indicate strong retention and effective assimilation of learning concept and principals, especially for the experimental group, which was invited in phase three of the flipped classroom process (post-class) to submit online the completion of activities requested by the teacher (additional problems to be solved, research into electrolysis applications).Given that every pupil in the experimental group has access to the platform (Myschool) through a single individual account, and based on the LMS management system's traceability and statistics, we can see that nearly all *EG* pupils have watched the videos and materials, taken the quizzes, and downloaded the documents, but the discussion on the forum has been insufficient. We may conclude that all members of the experimental group were devoted to the success of this study, whereas the pupils' reticence to participate in the forum can be explained by the fact that, given their modest levels of French, they cannot express themselves online in front of their peers.

The commitment of the pupils in both groups and the fact that they invested the necessary time in intensive preparation for summative test (the sum-test that counts towards the student's success) and the national exam are two reasons why the results of the summative tests are better than those of the post-tests. However, commitment alone is insufficient: the tools, teaching methods, and materials used make all the difference [25]. These three-phases teaching planning, supported by the flipped classroom method, resulted in a significant improvement in the experimental group's post-test and sum-test outcomes when teaching the second-year baccalaureate electrolysis course.

We can use the outcomes of many comparative previous research projects to support our findings. The academic performance of students in chemistry is said to be improved by the flipped classroom approach, according to several authors. Indeed, [26] observed that the success of the flipped chemistry course can be attributed to a range of factors, including the reinforcement of teacher and student responsibilities through pre- and in-class activities, the ability to quickly identify students with learning difficulties, and the enhancement of student-centered learning, collaborative skills, problem-solving abilities, communication confidence, and higher-order reasoning skills. We also cite [27, 28], which examined the difficulties that students encounter when studying electrochemistry and how the flipped classroom can support them and meet the needs of various students. Recently, [29], reported that flipped classroom's ability improve learning outcomes in redox reaction teachings. Other authors stated that the flipped classroom method increased student performance and knowledge retention in secondary chemistry instruction [30].

5. CONCLUSION

The current study focuses on the proposal of a course map and its implementation of Moroccan second-year baccalaureate program "electrolysis," with a purpose of improving students' learning performance using a flipped classroom method. The Learning Management System (LMS) was utilized for this design, which was carried out in three phases: pre-class preparation, in-class collaboration/training, and post-class research and consolidation. Two groups (control and experimental) were used and evaluated by a pre-test, a post-test and summative test.

The obtained data on the control and experimental groups in the tree tests were compared and analyzed using the Mann-Whitney U-test. The study found a substantial difference between groups in mastering levels of skill learning in favor of the experimental group. In the post-test and summative assessments, the experimental group earned higher mean scores than the control group (face-to-face teaching). These findings show positive results for the experimental group, which supports the effectiveness of implementing the proposed course map and its management supported by a flipped classroom method in improving learning outcomes in electrochemistry concepts.

ACKNOWLEDGMENT

The authors extend their gratitude to all, from the directors of the Regional Academy (AREF) of Beni Mellal-Khenifra and Provincial Directorate of Beni Mellal, of National Education, Primary Education, and Sports-Morocco, to the teachers and pupils who generously contributed their time and ideas to participate in this research. The authors would also like to express their gratitude to Mrs. Souad Samir, high school teacher, who took the time and effort to record the course in question. The authors would also like to convey their special thanks and appreciation to the creators of the educational platform Mr. Tariq Yassini and its partners for their cooperation.

REFERENCES

[1] L. Xiao, R. Larkins, L. Meng, "Track Effect: Unraveling the Enhancement of College Students' Autonomous Learning by Using a Flipped Classroom Approach", Innovations in Education and Teaching International, Vol. 55, No. 5, pp. 521-532, January 2018.
[2] M. Paristiowati, Y. Rahmawati, E. Fitriani, J.A. Satrio, N.A. Putri Hasibuan, "Developing Preservice Chemistry Teachers' Engagement with Sustainability Education through an Online Project-Based Learning Summer Course Program", Sustainability, Vol. 14, No. 3, p. 1783, February 2022.
[3] C.F. Herreid, N.A. Schiller, "Case Studies and the Flipped Classroom", Journal of College Science Teaching, Vol. 42, No. 5, pp. 62-66, 2013.
[4] L. Tomas, N.S. Evans, T. Doyle, K. Skamp, "Are First Year Pupils Ready for a Flipped Classroom? A Case for a Flipped Learning Continuum", International Journal of Educational Technology in Higher Education. Vol. 16, No. 1, 2019.
[5] N. Sookoo Singh, L.N. Boisselle, "How Does The "Flipped Classroom Model" Impact on Student Motivation and Academic Achievement in A Chemistry Classroom?", Science Education International, Issue 4, Vol. 29, No. 4, 2018.
[6] A. Lawson, C. Davis, J. Son, "Not All Flipped Classes are the Same: Using Learning Science to Design Flipped Classrooms", Journal of the Scholarship of Teaching and Learning, Vol. 19, No. 5, pp. 77-104, December 2019.
[7] D.C. Van Alten, C. Phielix, J. Janssen, L. Kester, "Effects of Flipping the Classroom on Learning Outcomes and Satisfaction: A Meta-Analysis", Educational Research Review, Vol. 28, p. 100281, June 2019.
[8] D.M. Bunce, E.A. Flens, K.Y. Neiles, "How Long can Pupils Pay Attention in Class? A Study of Student Attention Decline Using Clickers", Journal of Chemical Education, Vol. 87, No. 12, pp. 1438-1443, December 2010.
[9] A. Berdi, A. Sebbar, S. El Hadri, "The Coronavirus Pandemic and Distance Learning in Morocco", Journal of Educational Administration, No. 10, pp. 117-133, 2021.
[10] R. Bourqia, R. Chafaqi, T. Hari, A. Ait Hammou, H. Ait Mansour, "Teaching in the Time of Covid in Morocco", Thematic Report, National Evaluation Authority within the Higher Council of Education,

Training and Scientific Research, Higher Council for Education Training and Scientific Research (HCETSR), Rabat, Morocco, November 2021.
[11] MEN "Ministry of National Education", GENIE Program Management, Rabat, Morocco, 2020.
[12] Flipped Learning Network, "Definition of Flipped Learning", July 2015.
[13] L.W. Anderson, D.R. Krathwohl, "A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives: Complete Edition", Addison Wesley Longman, Inc., 2001.
[14] J.V. Boettcher, R.M. Conrad, "The Online Teaching Survival Guide: SIMPLE and Practical Pedagogical Tips", John Wiley and Sons, Google Scholar, p. 978, I SBN, 2016.
[15] S. Ko, S. Rossen, "Teaching Online: A Practical Guide", Routledge, Taylor and Francis, 2017.
[16] R.E. Mayer, "How Multimedia can Improve Learning and Instruction", J. Dunlosky, K.A. Rawson, (Eds.), The Cambridge Handbook of Cognition and Education, pp. 460-479, University of New England, Cambridge University Press, UK, February 2019.
[17] R. Palloff, K. Pratt, "Lessons from the Virtual Classroom", International Journal of Information and Communication Technology Education, Vol. 10, No. 2, pp. 93-96, 2013.
[18] J.L. Bishop, M.A. Verleger, "The Flipped Classroom: A Survey of the Research", The 2013 ASEE Annual Conference and Exposition, Vol. 18, pp. 1-23, Atlanta, Georgia, USA, 23-26 June 2013.
[19] C.C. Bonwell, J.A. Elson, "Active Learning: Creating Excitement in the Classroom", The 1991 ASHE-ERIC Higher Education Reports, ERIC Clearinghouse on Higher Education, The George Washington University, One Dupont Circle, Suite 630, Washington, DC, USA, 1991.
[20] J.C.Y. Sun, Y.T. Wu "Analysis of Learning Achievement and Teacher-Student Interactions in Flipped and Conventional Classrooms", International Review of Research in Open and Distributed Learning, Vol. 17, No. 1, pp. 79-99, 2016.
[21] X.L. Zheng, H.S. Kim, W.H. Lai, G.J. Hwang, "Cognitive Regulations in ICT-Supported Flipped Classroom Interactions: An Activity Theory Perspective", British Journal of Educational Technology, Vol. 51, No. 1, pp. 103-130, 2020.
[22] M.R. Raissouni, M. Abid, E. Chakir, "Design and Implementation of a New Teaching-Learning Model of Electricity Concepts in Middle School", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 53, Vol. 14, No. 4, pp. 92-100, December 2022.
[23] S. Abbott, (Ed.), "Bloom's Taxonomy", The Glossary of Education Reform, 19 January 2015.
[24] N. Veiga, F. Luzardo, K. Irving, M.N. Rodriguez Ayan, J. Torres, "Online Pre-Laboratory Tools for First-Year Undergraduate Chemistry Course in Uruguay: Student Preferences and Implications on Student Performance", Chemistry Education Research and Practice, Vol. 20, No. 1, pp. 229-245, 2019.
[25] R. Wikandari, A.W. Putro, D.A. Suroto, F.A. Purwandari, W. Setyaningsih, "Combining a Flipped Learning Approach and an Animated Video to Improve First-Year Undergraduate Students' Understanding of Electron Transport Chains in a Biochemistry Course", Journal of Chemical Education, Vol. 98, No. 7, pp. 2236-2242, 2021.
[26] S.A. Alias Anand, "Flipped Pedagogy: Strategies and Technologies in Chemistry Education", Materials Today, Vol. 47, pp. 240-246, 2021.
[27] M.T. Ali, A.R. Woldu, A.G. Yohannes, "High School Students' Learning Difficulties in Electrochemistry: A Mini Review", African Journal of Chemical Education, Vol. 12, No. 2, pp. 202-237, 2022.
[28] L. Zai, R. Listyarini, "Application of Flipped Classroom to Improve Learning Outcomes in Redox Reaction Lesson", Hydrogen: Journal of Education Kimia, Vol. 11, No. 1, pp. 68-73, 2023.
[29] A. El Kasri, M. Abid, A. Ouasri, A. Lebkiri "The Effect of a new Teaching Model Using Computer Simulations on Pupils' Chemistry Knowledge and Skills: A Case Study", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 57, Vol. 15, No. 4, pp. 198-208, December 2023.
[30] M.D. Ryan, S.A. Reid "Impact of the Flipped Classroom on Student Performance and Retention: A Parallel Controlled Study in General Chemistry", Journal of Chemical Education, Vol. 93, No. 1, pp. 13-23, 2016.

BIOGRAPHIES

Name: **Amina**
Surname: **El Kasri**
Birthday: 05.02.1990
Birthplace: Beni-Mellal, Morocco
Bachelor: Industrial Electronics and Computing, Department of Physics, Multidisciplinary faculty, Sultan Moulay Slimane University, Beni-Mellal, Morocco, 2013
Master: Teaching and Training Professions in Physics and Chemistry, Department of Physics, Faculty of Sciences, Ibn Tofail University, Kenitra, Morocco, 2017
Doctorate: Didactics of Sciences and Education Sciences, Department of Chemistry, Faculty of Sciences, Ibn Tofail University, Kenitra, Morocco, 2023
Research Interests: Teaching-Learning, ICT, Chemistry, Physics, Simulation
Scientific Publications: 3 Papers

Name: **Mohammed**
Surname: **Abid**
Birthday: 07.10.1969
Birthplace: Sidi Bennour, Morocco
Bachelor: Chemistry, Department of Chemistry, Faculty of Sciences, Ibn Tofail University, Kenitra, Morocco, 1995
Master: Chemistry, Department of Chemistry, Faculty of Sciences, Ibn Tofail University, Kenitra, Morocco, 1997
Doctorate: Applied Chemistry, Department of Chemistry,

Faculty of Sciences, Ibn Tofail University, Kenitra, Morocco, 2000
The Last Scientific Position: Prof., Regional Center for Education and Training Professions, Rabat, Morocco, Since 2011 - Assoc. Prof., Faculty of Sciences, Ibn Tofail University, Kenitra, Morocco, Since 2015
Research Interests: Science Didactic, Chemistry of Glasses
Scientific Publications: 30 Papers

Name: **Ahmed**
Surname: **Lebkiri**
Birthday: 01.05.1958
Birthplace: Beni Mellal, Morocco
Bachelor: Organic Chemistry, Department of Chemistry, Faculty of Sciences, Mohamed V University, Rabat, Morocco, 1982
Master: Organic Chemistry and Macromolecules, Faculty of Sciences and Technologies, Department of Chemistry, Lille 1 University, France, 1984
Doctorate: Study of Role of the Carboxylic Side Chain of Aspartic and Glutamic Acids in Complexation of Tetrapeptides with Transition Metal Ions, Department of Chemistry, Lile 1 University, France, 1987
The Last Scientific Position: Prof., Department of Chemistry, Faculty of Sciences, Ibn Tofail University, Kenitra, Morocco, Since 1988
Research Interests: Advanced Materials, Process Engineering
Scientific Publications: 60 Papers