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DESIGN AND IMPLEMENTATION OF A NEW TEACHING-LEARNING MODEL OF ELECTRICITY CONCEPTS IN MIDDLE SCHOOL

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Abstract- The objective of this article is to design, construct and test a new teaching-learning model of electricity concepts in middle school. This model is developed by integrating the inquiry-based learning approach, recommended in the official Moroccan middle school's physical sciences program, the flipped classroom model and analogy for teaching electricity. To do this, we first analyzed the current situation and explained the need for such a project in the physical science curriculum of Moroccan middle school, then designed and developed the model and finally implemented it with a sample of 83 middle school pupils. In this study, we followed a quasi-experimental research design wherein a pre-test and a post-test were deployed for the experimental and control groups. This study found that pupils' means scores and outcomes after the intervention were significantly in favor of the experimental group.

Keywords: Integrated Model, Middle Schools, Electricity, Teaching, Learning.

1. INTRODUCTIONAND PROBLEMATIC

In a changing world where information is ubiquitous and technology opens up new opportunities and challenges every day, it become necessary to encourage a genuine scientific culture that allows the use of acquired skills in everyday life [1]. To this end, several countries around the world have adopted new educational policies and a renewal of the teaching of experimental sciences by seeking to make learning more active and more motivating [2]. In Morocco, since the undertaken reform in the early 2000s, which is the result of the national charter of education and training, the designers of the physical sciences programs have adopted the competency-based approach [3]; where contents are transposed into academic activities in order to accomplish tasks and acquire work methodologies. This approach derives its principles from the constructivist and socio-constructivist theories of learning, which are operationalized by active methods [4]. Among the active methods included in the official Moroccan programs of teaching physical sciences at middle schools, we can cite the inquiry-based model, the problem-solving model and learning by project [3]. However, this project does not easily find its place in the daily school practices in Morocco [5] and elsewhere [3]. Indeed, it seems that the majority of physical science teachers find these teaching models difficult to implement, especially because of the time required for their implementation, the lack of autonomy of students [5], the class size (often we have overcrowded classes) [6] and the lack of necessary didactic materials to carry out the experiments [5].

In addition, the students generally have difficulty assimilate the concepts of electricity, which are abstract and complex [7]. These influence the motivation of learners and make the implementation of the teaching models mentioned above even more difficult, especially when teaching basic electricity concepts, such as the intensity of electric current (I) and electrical voltage (U). Faced with these problems, many teachers have turned to teaching that focuses on the transmission of knowledge, where the teacher is the expert and the main responsible for this transmission [8], and consequently learning in class will always be based on listening and memorization activities. Hence, the question arises as to how Moroccan physical science teachers can use the active learning models proposed in the official programs while overcoming the difficulties mentioned above.

Therefore, it is important to design, develop and implement a new teaching-learning model that takes into account all of the above remarks. In addition, it incorporates stimuli that can positively influence learning [9]. More than that, the strategic vision 2015-2030 (a new education reform in Morocco) recommends strengthening the integration of technology to improve the quality of learning [10]. Similarly, our model enhances individual student motivation by creating a classroom social environment that fosters learners who are able to engage in the deep and sustained comprehension activities necessary to refine conceptual knowledge. [11]. Furthermore, it uses analogy to facilitate the understanding of abstract concepts of electricity. The history of science has already shown how analogies can play a positive role in the construction of new scientific knowledge [7]. Ultimately, it can be said that all these measures allow teachers to respond more effectively to the individual needs of students, and consequently to integrate the Universal Design for Learning (UDL). The UDL aims to provide more flexibility in the presentation of instructions, more means of expression for students and more opportunities for students' engagement in the construction of learning [12].

Our work proposes a new model of teaching-learning of electricity in the middle school, which is developed from the learning model based on the inquiry approach pronounced in the Moroccan official programs, taking into account the difficulties mentioned above. Its main objective is to place the learner at the heart of the teaching-learning process; it is the learner who develops his or her knowledge through interaction, research and experience. However, the teacher is a coach who provides tools and ways for reflection. He integrates the appropriate digital tools to gain time and autonomy, he uses analogy to introduce abstract concepts of electricity and creates an environment of social debate to enhance individual learner motivation, and he integrates Universal Design for Learning; (UDL) to foster quality learning for all students.

Hence the main question of this work is: what model of learning can be adopted for teaching-learning electricity at the middle school in the Moroccan context?

Moreover, the questions that derive are:

- How can the problems of time-management, learner autonomy, and complexity of electricity concepts and lack of motivation can overcome in an electricity learning model?
- Is there a statistically significant gap, based on the pre-test results, between learners in the two groups (experimental and control)?
- Is there a statistically significant gap, based on the pre-test results, between the two sexes (boys and girls) in the two groups?
- Is there a statistically significant gap, based on the post-test results, between the performances of learners in the two groups of learners after the application of the new learning model?
- Is there a statistically significant gap, based on the post-test results, between the performance of boys and girls in the experimental group of the learners after the application of the new learning model?

2. CONCEPTUAL FRAMEWORK

Our study proposes a model based on the inquiry learning, the flipped learning and analogy. In this paragraph, we will first define what a pedagogical model is, and then we will give the seven times of the inquiry-based learning model as it has been proposed in the official Moroccan curricula and a simple definition of the flipped learning model. At the end, we will propose a description of our new model.

2.1. Didactical Model

At First, a distinction must be made between a pedagogical model and a properly scientific model. While the main purpose of the scientific model is to explain a fragment of reality by making it possible to predict its behavior, the pedagogical model aims to provide a representation that can accompany and clarify action. It is a model to act by understanding how we act. In this sense, the current dictionary of education states that a pedagogical model is a model that presents a specific arrangement of activities and interventions. It constitutes a representation of a particular type of teaching; a set of interrelated pedagogical activities that are based on a representation of the human being, on learning and on society [13].

2.2. Learning Model Based on the Inquiry

Inquiry-based learning is a didactic method designed to prepare and involve learners in the learning of knowledge and skills through planned, structured, and open-ended activities and tasks in a realistic environment to describe and understand the real world around us. Therefore, the construction of learning by adopting this approach is done according to a process that includes the following seven times: problem-situation; appropriation of the problem by the students; formulation of explanatory hypotheses; investigation; presentation and exchange of results; structuring of knowledge and mobilization [3].

2.3. Flipped Learning Model

There has been a growing interest in recent years in the flipped learning [14]. It is a pedagogical approach with a mixed learning framework where face-to-face and virtual teaching are combined [15]. Moreover, it is flexible both in terms of time and place. Generally speaking, it is a conception where the classroom should become a place where learners exchange and mobilize the resources of their understanding of the subject matter, through practical exercises and other activities mainly carried out in groups. In order to do this, they prepare themselves before the class, for example, by reading, or watching video clips on the material that will be worked on in the class. It can be said that it is a student-centered learning culture that allows them to revisit the course elements several times and learn at their own pace [16].

2.4. Use of Analogy for Teaching Electricity

Concepts of electricity are particularly abstract and complex in a way that makes them difficult to understand and dependent on patterns, analogies, and metaphors [7]. For this purpose, the use of an analogy helps to explain the abstract concept by identifying similarities between objects or events in the students' world and the phenomenon under examination. Analogies can provide a visualization of abstract concepts and thus increase students' motivation. In our case, an analogy with hydraulics can be useful for understanding and addressing common misconceptions about the electric current [17].

2.5. Developing Content for Model

First of all, our model is based on inquiry-based learning by adopting almost all of these steps, with small corrections regarding the grouping of some of these steps. Secondly, the learning model is based on the flipped learning model; alternating between in-class and out-of-class learning. In developing this model, we proceeded by eliminating the problems of the implementation of the inquiry-based learning model mentioned in Table 1, namely lack of time, lack of students' autonomy, class size (often crowded classrooms) and lack of necessary didactic materials to carry out experiments (See Table 1 which illustrates these problems and the solutions proposed by our model). In addition, learners have major difficulties in understanding the abstract concepts of electricity, and low motivation towards their learning.

Table 1. The implementation's problems of the inquiry-based learning model and the proposed solutions

The problems	The Proposed solutions
Lack of time	- Alternating work (in and out-of-class)
The difficulty of the concepts	- The analogy with hydraulics - Use of simulation
Lack of teaching materials	- Use of simulation
Lack of autonomy and motivation	- Use of simulation - Collaborative activities
Crowded classrooms	- Use of simulation

So, to overcome these problems it was proposed to:

- Merge between in-class and out-of-class students' work, which saves time and gives learners more autonomy [16].
- Combine both real practical work and computer simulation methods in order to fill in the gaps that either method may present. Indeed, using simulations makes it possible to shorten the duration of time-consuming experiments [18], overcome the lack of experimental materials [9], and improve motivation and interest in the classroom [19]. Furthermore, inquiry-based simulation can help learners overcome their learning difficulties and partially solve the problems of misconceptions [20]. To this end, participating teachers were offered the website (http://phet.colorado.edu)developed by the University of Colorado at Boulder, and which offers free downloadable learning simulations in physical science [21]. However, several schools in Morocco and developing countries do not have access to the internet, computer laboratories and therefore simulation software, which explains our choice of combinations. Moreover, Abdullah and Shariff find that the combination of real-world practical work and inquiry-based computer simulation methods with collaborative learning is very effectively used to promote scientific reasoning and conceptual assimilation of electrical circuits [22].
- Create a communicative environment, collaborative activities and social debates to attract the interest of learners and ensure their involvement [23]. Moreover, debates improve students' analytical reasoning skills [24].
- Using an analogy in the field of hydraulics allows students a high degree of organization of new knowledge and therefore allows overcoming the complexity of electricity concepts [7]. This analogy will take place at the end of the session in order to reinforce the acquisitions and modify the misconceptions taking into account the confusions that can be generated.

In short, it can be said that these propositions are in perfect harmony with the principles of Universal Design for Learning (UDL). In fact, our model offers various ways to personalize the construction of learning (either through ICT, colleagues or teachers). Also, it offers several means of action and expression (combining between individual and group work, between manipulation and the use of simulations). In addition, it offers various opportunities to stimulate learners' interest by fostering collaboration and varying resources through the use of analogy.

Therefore, the steps of our model (noted SRPCM) are shown in Figure 1, and described as:

- Starting problem situation (in-class): the teacher presents an interesting and stimulating starting situation problem. It helps learners to take ownership of the problem and encourages them to think and ask questions. The situation is followed by research questions relating to the new concepts that will be developed in the lesson. These questions can lead to cognitive and socio–cognitive conflicts. The answer to each question will be considered as the student's hypothesis about the concept under consideration. It is presented at the end of the last session before our session starts. In addition, students are encouraged to use the website (http://phet.colorado.edu)to confirm or disconfirm these hypotheses. This site allows simulation with a flash animation that allows students to manipulate and build electrical circuits with the necessary components, and to take measurements (a screenshot of the simulation used, is shown in Figure 2).
- Research (out-of-class): the learners work in groups outside the classroom to take ownership of the problem to be solved, to answer the questions (give hypotheses), to propose investigation scenarios and to confirm these hypotheses (with a scheme if necessary). For this interest, the teacher has already distributed a student worksheet to be filled, which includes: the hypotheses, the proposed protocol, the observations and the conclusion (the observations and the conclusion are to be filled in the class).
- Presentation and investigation (in–class): the teacher divides the learners into groups, and they discuss the results in groups. The reporters of each group communicate within the class the assessment of their out-of-class work, and the debate takes place between the students with a confrontation of the proposals. At the end, they implement the chosen scenarios under the supervision of the teacher by combining the experimental and simulation activities (depends, an experimental or simulation activities are used). Afterwards, the teacher helps the students to choose a suitable synthesis.
- Consolidation (in-class): The aim of this stage is to deepen the acquired knowledge. The teacher presents a video that shows the analogy between electrical and hydraulic circuits (for example the video on the site https://www.pccl.fr).Afterwards, he/she opens a discussion among the students under his/her guidance to consolidate the acquired knowledge, to understand the abstract concepts of electricity by comparing them to the

concrete concepts of hydraulics and to correct the misconceptions while clarifying the limits of our analogy.

• Mobilization of knowledge (in–class and out-of-class): the teacher proposes new problems allowing the implementation of the acquired knowledge in new equivalent situations.

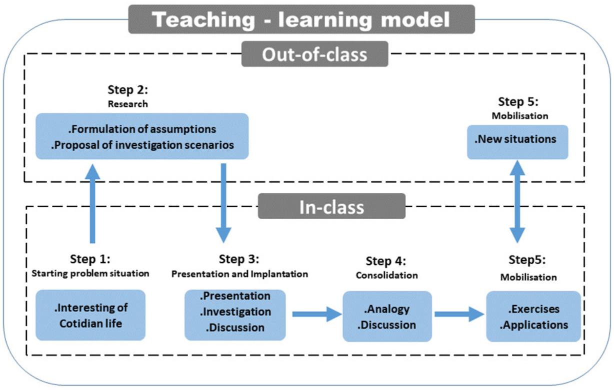

Figure 1. The steps of the SRPCM teaching-learning model

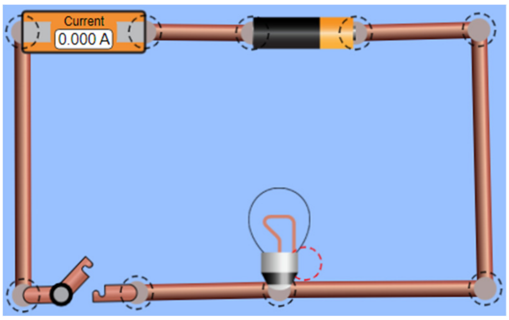

Figure 2. Screenshot of a simulation [25]

Therefore, the goal of our model is to put the pupil in a teacher-guided research situation, a situation where the pupil must test his or her hypothesis in a group setting and outside of the classroom by combining simulation and real experimental activities. To achieve this goal, the pupil is obliged to situate himself in relation to the obtained results, which will allow him to think critically, and will also facilitate an environment of fruitful social debate during the exchange of results.

In addition, the visualization of the video already mentioned in the consolidation step that shows the analogy between electrical circuits and hydraulic circuits, will help pupils to structure their knowledge and overcome misconceptions about basic electrical concepts. Note that in the SRPCM teaching-learning model, there is a flexibility to go back to previous steps, depending on the progress of the session.

3. METHODOLOGY

3.1. Research Goal

In this study, a quasi-experimental design was applied to examine the impact of SRPCM teaching-learning model. This work was carried out during the academic 2020/2021 school year, using a pre-test and post-test for the two groups (experimental and control).

3.2. Sample Collection

This work concerns the implementation of a new SRPCM teaching-learning model of electricity in Moroccan middle schools for a random sample of 83 pupils in the first year of meddle school with 41 in the experimental group and 42 in the control group in the province of Tetouan. These included 39 boys, 44 girls, all in the 12-14 age range.

3.3. Data Collection

For the purposes of this research project, the lessons introducing the basic concepts of electricity, namely (I) and (U), were chosen. The expected learning outcomes after the teaching, which are extracted from the official Moroccan programs of teaching physical sciences at middle schools, are presented in Table 2.

Table 2. Expected learning outcomes [3]

Lesson Title	Outcomes
Direct electrical current	- Know the sources of direct electric current - Know the properties of direct electric current - Use measuring devices - Know the units of current intensity and electrical voltage in SI

Then, two teachers were assigned to teach the lessons (each with five years of experience), and these teachers were given a training session to prepare them for their tasks, providing them with the necessary documents (the pre-test, post-test, the websites (http://phet.colorado.edu; https://www.pccl.fr) and the necessary teaching materials). At the end of this training, a pedagogical sheet of the lesson as well as a pupil's worksheet was elaborated. The administered pre-test and post-test were used to evaluate the SRPCM model and were approved by a panel of two expert's teachers and two educational consultants. Their opinions on the clarity and appropriateness of the questions were considered.

The post-test, composed of 15 items, contains mainly two sections: the first section deals with the personal data of the respondents, and it includes two items, gender and age. The second section (13 items) includes questions that take into account the expected learning outcomes (Table 2) and misconceptions related to the concepts in question cited in several previous studies [26]. Then, we attended the course presented by these teachers with the experimental group, which benefited from SRPCM teaching learning model. However, the control group received instructions by the traditional method (without SRPCM model).

Our lesson was taught for 4 hours as an intervention session. After that time, we conducted the post-test to identify the instructional effect of the intervention. We administered the pre-test one week before the intervention to assess the knowledge of learners in both groups in relation to the content of the electricity lessons already seen this year (see the titles of these lessons and the objectives to be achieved in each lesson in Table 3). The pre-test consists of 17 closed questions covering many of the objectives of the lessons in question

Table 3. The objectives and lessons' title of the pre-test [3]

Lessons' title	Objectives
The simple electrical circuit	. Know the elements of a simple electrical circuit . Draw a diagram of a simple electrical circuit using standardized symbols . Perform the assembly of a simple electrical circuit from a diagram and vice versa . Defining an electric dipole
Electrical conductor and insulator	. Defining an Electrical Conductor and Insulator . Distinguishing an Electrical Conductor and Insulator . Know some dangers of electric current and the precautions to take
The different types of electrical assembly	. Know the two kinds of electrical assembly . Know the interest of electrical assembly in bypass . Carry out an electrical assembly in series and in bypass from a diagram and vice versa

3.4. Data Processing

All the collected data was processed by SPSS version 23 software to determine the means and standard deviations value. Also, to perform the normality and t-test.

3.5. Data Analysis

In response to the obtained data from the pre-test and post-test, the percentages of correct responses for the items were calculated to determine the levels of achievement of the learning outcomes, Descriptive (average and standard deviations) and inferential statistics (normality test and t-test) were performed to analyze the obtained. All scores were interpreted at $p<0.05$.

4. RESULTS AND DISCUSSION

Our main aim is to research the effect of the SRPCM model on pupils' learning electricity concepts. To do this, firstly, we examined then compared the results of the pre-test based on the group (experimental and control) and the gender of the students. Secondly, and in the same vein, we compared the results of the post-test.

4.1. Results and Discussion of the Pre-Test

4.1.1. Pre-Test Results According to the Group

The normality of the data is measured using the Shapiro-Wilk method (data are normally distributed if the Shapiro-Wilk p-value is greater than the value 0.05). The results of the normal distribution in the two groups (control and experimental) before the intervention are given in Table 4, the Shapiro-Wilk p-value in the experimental group is 0.309 higher than the significant value of 0.05 (the distribution is normalized). In addition, the p-value for the control group is 0.472 above the significant value of 0.05 (the distribution is also normalized). Therefore, we can use the t-test to compare the average of the experimental group with that of the control group.

Table 4. Normality tests for pre-test based on group and gender

	Statistic	*Df*	*Sig*
Experimental	0.969	41	0.309
Traditional	0.974	41	0.472
Girls	0.944	39	0.053
Boys	0.964	39	0.249

In order to make sense of the results of the research, we will first compare students' averages (scores are out of 100), the subject of the study, according to the group to which they belong. (See results in Table 5)

Table 5. Means of the pre-test according to the group and gender

		N	Mean*	Standard deviation
Group	Experimental	42	58.68	10.96
	Traditional	41	58.26	11.46
Gender	Girls	44	61.76	11.31
	Boys	39	55.20	9.50

* Scores are out of 100

The collected data from the pre-test shows that the learners in the experimental group the average pre-test score is 58.68 with a standard deviation (SD) of 10.96, and the control group the average pre-test score is 58.26 with an SD of 11.46. These results answer our research question about the mean pre-test score for the two groups and show that the two groups have a very similar level in the electricity branch. However, there is still a small difference: to verify the significance of this difference, we used the independent sample t-test to compare the average of the two independent samples. The significance level α of 0.05 was used to interpret the results that are presented in Table 6. According to the results of the independent samples t-test, the "t" value is not significant [t = 0.169, p > 0.05]. Therefore, it can be concluded that there is no significant gap between the two groups (control and experimental). In other words, both groups had the same level of knowledge before the intervention. These results allow us to approve our quasi-experimental methodology using a pre- and post-test.

Table 6. The t-test of independent samples (pre-test) basing on group

		Equal variances assumed	Equal variances not assumed
Levene's test for equality of variances	*F*	0.131	
	Sig	0.717	
t-test for equality of means	*T*	0.169	0.169
	Df	81	80.968
	Sig (2-tailed)	0.866	0.866

4.1.2. Students' Performance in the Pre-Test by Gender

The results of the normality in the two groups (female and male) before the intervention are presented in Table 4. The Shapiro-Wilk p-value in the female group is 0.053 higher than the significant value of 0.05 (the distribution is normalized). In addition, the p-value for the male group is 0.249 above the significant value of 0.05. Therefore, we can say that the distribution is normal, and therefore we can use the t-test to compare the average of the both groups.

From the results in Table 5, we can see that female pupils had a mean pre-test score of 61.76 higher than the overall mean with a standard deviation (*SD*) of 11.31 and male pupils had a mean pre-test score of 55.2036 lower than the overall mean with an *SD* of 9.50. To verify whether this gap is significant, we employed the independent sample t-test (Table 7). The following results were found [t = 2.840, $p < 0.05$] and therefore it can be stated that there is a significant gap between the performance of boys and girls on the pre-test in favor of girls. These results are consistent with the results of other studies such as TIMSS (2015) regarding students' performance by gender in science [27], and Ben Ouahi (2021) who found that girls' performance is better than that of boys when teaching Ohm's law by simulations in the third year of Moroccan middle school [9]. This difference, although statistically significant, remains minimal and lower than that recorded in other subjects such as reading and comprehension. In addition, girls outperform boys in science in other countries comparing to Morocco such as Jordan and Saudi Arabia [28].

Table 7. The t-test of independent samples (pre-test) based on the gender

		Equal variances assumed	Equal variances not assumed
Levene's test for equality of variances	*F*	0.627	
	Sig	0.431	
t-test for equality of means	*T*	2.840	2.870
	Df	81	80.786
	Sig (2-tailed)	0.006	0.005

4.2. Results and Discussion of the Post-Test

4.2.1. Post-Test's Results According to the Adopted Model

Normality of the collected data was measured with the same Shapiro-Wilk test. The results of the normal distribution in the two groups (control and experimental) after the intervention are illustrated in Table 8. The p-value in the experimental group is 0.069 higher than the significant value of 0.05 (the distribution is normal). In addition, the p-value for the control group is 0.222 which is also higher than the significant value (the distribution is normal)

Table 8. Tests of normality (post-test) based on the model and gender

	Statistic	*df*	*Sig*
Experimental	0.950	41	0.069
Traditional	0.964	41	0.222
Girls	0.946	19	0.332
Boys	0.918	19	0.104

The collected data from the post-test in both groups (experimental and control) allowed us to draw the results in Table 9, where the mean and standard deviation for both groups (experimental and control) were calculated.

Table 9. Means of the post-test according to the model and gender

		N	Mean*	Standard deviation
Model	Experimental	41	81.0507	10.75515
	Traditional	42	50.3663	12.62288
Gender	Girls	21	82.5175	10.66454
	Boys	19	78.5425	10.44032

* Total test score of 100 points

These results show that pupils in the experimental group achieved 81.05 of the learning level scores with a standard deviation of 10.75, while students in the control group achieved only 50.36 of the scores, with a standard deviation of 12.62. Therefore, the teaching practices related to the proposed new teaching model had a noticeable effect on the improvement of the results in the experimental group. In addition, several of the students' misconceptions about electric current and voltage were corrected. For example, for the circulatory design with current "depletion", respectively 92.6% and 87.8% of the experimental group answered the related questions correctly after the intervention.

To make sense of these results, and to confirm that there is a significant gap between the results of the two groups, the independent sample t-test was used. The results of the comparison are illustrated in Table 10.

Table 10. The t-test of independent samples (post-test) based on the adopted model

		Equal variances assumed	Equal variances not assumed
Levene's test for equality of variances	*F*	0.831	
	Sig	0.365	
t-test for equality of means	*T*	11.907	11.930
	Df	81	79.577
	Sig (2-tailed)	0.000	0.000

The findings of the t-test show that there is a significant gap between the average scores of the two groups (experimental and control) [t = 11.90, $p < 0.05$]. Thus, we can confirm that a significant difference exists between the both groups in favor of experimental group.

4.2.2. Students' Performance in the Post-Test by Gender in Experimental Group

The results of the normal distribution in the experimental group (female and male) after the intervention are presented in Table 8. The Shapiro–Wilk p-value in the female group is 0.332 above the significant value of 0.05 (the distribution is normalized). In addition, the p-value for the male group is 0.104 above the significant value of 0.05. Therefore, we can say that the distribution is normalized, and therefore we use the t-test to compare the averages of the two groups.

From the results in Table 9, we can see that female pupils had a mean post-test score of 82.54 higher than the overall mean with a standard deviation (SD) of 10.66 and male students had a mean post-test score of 78.54 lower than the overall mean with an SD of 10.44. To check whether this gap is significant, we used the independent sample t-test (Table 11). The following results were found [t = 1.20, $p > 0.05$] and it can therefore be concluded that there is no significant difference between the performance of boys and girls in the experimental group at post-test. These results are consistent with the results obtained by PINA (2019) which show that at the middle school level, the obtained score in physics-chemistry by Moroccan girls and boys, does not show a significant gap between girls and boys [28]. Indeed, the results of this report show that there are some differences in learning, between girls and boys in favor of girls, but this difference is not significant in physical science branches.

Table 11. The t-test of independent samples (post-test) based on the gender

		Equal variances assumed	Equal variances not assumed
Levene's test for equality of variances	*F*	0.044	
	Sig	0.836	
t-test for equality of means	*T*	1.202	1.204
	Df	39	38.359
	Sig (2-tailed)	0.237	0.236

Therefore, we can say that there is a significant difference favoring the experimental group in the post-test, which benefited from learning using SRPCM model, showing that this model can positively influence learning in electricity. It also corrects many of the pupils' misconceptions about the concepts in question (current intensity and electrical voltage). In addition, this new SRPCMmodel overcomes the difficulties that prevent teachers from using active learning models in the Moroccan context, namely: time-management problems, lack of student autonomy, class size, lack of necessary didactic materials to carry out the experiments, the difficulties of electricity concepts due to their abstract nature, and the lack of learners' motivation. These results have a great similarity with the research findings of Jemaa and Boilevin (2016) who confirmed that the use of simulation in an inquiry-based teaching approach can help students overcome their learning difficulties [20].

Also, Umesh Ramnarain (2017) suggests that the use of simulations in teaching electrical circuits reduces the number of misconceptions previously maintained by learners [29]. On the other hand, the alternation between the learners' work in the classroom and elsewhere allowed us to save time, which is in perfect agreement with the results of other authors' study [15]. In addition, the social classroom environment allowed us to support the creativity of learners and engage them in the deep and enduring necessary comprehension activities to retain conceptual knowledge [24]. Finally, the use of the analogy with hydraulics allowed us to realize the studied concepts, given their abstract character, which makes them very difficult to understand. These results are consistent with many previous studies that have confirmed that the utilization of analogies in the teaching and learning of electricity, promotes a good understanding of these complex concepts [11, 30].

5. CONCLUSION

This study attempted to design and validate a new integrated teaching-learning model (SRPCM) of electricity concepts in Moroccan middle school with a random sample from the Provincial Directorate of the Ministry of National Education of Tetouan-Morocco, regarding the basic concepts of electricity (I and U). Statistical collected data from the semi-experimental research using a pre-test and a post-test of two groups (experimental and control), showed that learners in the experimental group who were taught by this new SRPCM model were more successful than learners in the control group taught by the traditional model.

Indeed, learners in the experimental group have an average post-test result of 82.36 with a standard deviation (SD) of 12.89, while learners in the control group have an average post-test result of 51.83 with an SD of 15.76. It should be noted that before our intervention, the means of the experimental and control groups were almost equal (58.68 and 58.26, respectively). In addition, this model helped correct several of the learners' misconceptions about electricity concepts and helped overcome the difficulties that prevent teachers from using active learning models in the Moroccan context.

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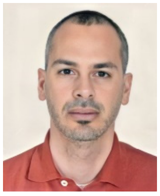
BIOGRAPHIES



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