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

March 2024	Issue 58	Volume 16	Number 1	Pages 347-353

DESIGN AND EXPERIMENTATION OF A DIDACTIC DEVICE FOR CONCEPTUAL CHANGE: THE CASE OF LEARNING ELECTRICITY

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Abstract- Our study focuses on the design and experimentation of a didactic device aimed at remedying erroneous conceptions in physics, more specifically in electricity, among college high school learners. It describes the process of designing the device, which aims to identify conceptual difficulties and propose specific didactic activities to remedy them. It is therefore an approach involving high school learners in practical activities and experiments related to electricity. Experimental results showed a significant and remarkable improvement in learners' understanding of electricity concepts. The device helped to address conceptions and errors, promoting a better understanding of the fundamental principles of electricity. Such devices can play a crucial role in improving the teaching and learning of scientific concepts among secondary school learners.

Keywords: Conceptual Change, Conceptions, Teaching, Learning, Electricity.

1. INTRODUCTION

Learning is a highly complex human phenomenon, governed by a number of psychological, social, didactic, pedagogical, and epistemic factors [4, 5, 9]. However, learning does not begin in a vacuum because the mind is never blank [3]. The psychology of learning shows that the learner constructs knowledge as soon as he or she comes into contact with the outside world [7]. Most of the time, these representations are detrimental to the quality of learning, as they resist the learning of so-called scientific or institutional knowledge [20]. In fact, the learner explains and analyzes everything he or she receives in terms of new knowledge, based on these representations (the already here) [6], hence the need to take them into account for any effective teaching-learning, by resorting to the process of conceptual change.

The aim of this work is to experiment with and validate a didactic device enabling the teacher to remedy learners' conceptions (representations) about electricity. With this in mind, we pose the following research question: To what extent is this proposed conceptual change didactic device effective in improving learners' learning? The general hypothesis of this research is that the use of the proposed conceptual change didactic device has positive effects on improving the quality of learners' learning.

2. THEORETICAL FRAMEWORK

Several works in epistemology and psychology [1-3] have already advocated that learners bring their empirical knowledge to the physics-chemistry classroom, which can create learning obstacles during the acquisition of scientific knowledge. This empirical knowledge often contains identifiable conceptions that are not in line with scientific concepts and present a certain resistance to teaching, thus necessitating a conceptual change [2].

2.1. Conceptual Change

In didactics, learning is mostly seen as a process of conceptual change [2], hence the need to study the conditions and ways of this change. However, what is conceptual change? In addition, what are its different models?

2.1.1. What is the Conceptual Change?

Conceptual change is a slow and complex process. Betty [1] defines it as the process by which an individual's initial conceptions evolve towards a more precise conception in line with scientific knowledge. Deaudelin, et al. [18] add that this process involves the modification of an individual's mental conceptions, made up of constructed elements and their interrelationships. To facilitate this change, the teacher must provide the learner with a new alternative explanatory model, also known as "concept reconstruction". In the absence of a new conception, the learner will find it difficult to abandon his or her old, erroneous conception.

Registered: 230908 Article Info: 1750 Accepted: 240221
Reserved: 231112 Available: 240331

This reconstruction therefore involves creating a new concept and integrating it in such a way that it is as comfortable as the previous one [21]. Learners will generally choose a new explanatory model if they are dissatisfied with the old one or if the new concept enables them to answer more questions [22]. Posner, et al. [23] defined the conditions necessary to produce a conceptual change as dissatisfaction with the initial conceptions, comprehensibility, plausibility, and fruitfulness of the new conception. Once these conditions have been met, conceptual change models are used to overcome obstacles and learning difficulties [1].

2.1.2. The Different Models of Conceptual Change

Conceptual change models are many and varied [2]. In this work, we present the models most frequently cited in the literature:

2.2.1. The Posner, Strike, Hewson and Gertzog Model (1982)

The Posner, Strike, Hewson and Gertzog (1982) model is one of the most widely cited in the literature [1]. Based on Piaget's concepts of assimilation and accommodation and the structure of scientific revolutions proposed by Kuhn (1962), it aims to explain how science progresses and evolves over time, with particular emphasis on radical changes in scientific paradigms [27]. This model focuses on problem solving by learners in order to create an imbalance between their initial conceptions and new information, thus provoking cognitive conflict. This conflict leads to a re-evaluation and modification of conceptions to resolve the conflict [3]. The model proposes a sequence of stages that learners go through when modifying their conceptions, including the stages of preconception, confrontation, confusion, restructuring, and application.

However, this model has been criticized for several reasons. According to Clement [24], learners have different initial conceptions, which makes it difficult to create a cognitive conflict that would affect the majority of them. Furthermore, Pintrich, et al. (1993) highlight the lack of motivational and emotional aspects of learners in this model [25]. Finally, this model does not take into account the possibility that a misconception may be useful in the learning process, considering it instead as an obstacle to the learner's progress [26].

2.2.2. Giordan's Model (1989)

This model takes its name from the allosteric model, in analogy with allosteric proteins that change configuration according to their environment [1]. Similarly, hemoglobin changes configuration when it picks up oxygen [28]. Giordan's model sees this conceptual change as a process of profound transformation of knowledge, but he also emphasizes that this process simultaneously involves a deconstruction and reconstruction of pre-existing conceptions, thus provoking a deliberate cognitive conflict in learners [28].

According to this model, knowledge acquisition arises from complex expansion activities in which the learner mobilizes existing knowledge and produces new meanings better adapted to answer identified questions or challenges [29]. Giordan and his colleagues have developed a didactic environment to foster the transformation of conceptions, in which parameters such as meaning-making, knowledge mobilization, self-confidence, imagination, etc. are to be stimulated and taken into account during teaching, depending on the category of pedagogical practice to which they relate [1]. Allosteric learning thus implies a new relationship to knowledge and new functions for the teacher. The latter's role is not limited to simply communicating knowledge or giving a priori demonstrations but also involves interacting with the learner's learning strategies to facilitate the act of learning [29].

2.2.3. DiSessa's Model (1993)

Unlike Posner, this model emphasizes the importance of learners' intuitive knowledge and interpretive habits, which are deeper and more fundamental than a simple initial conception [28]. DiSessa calls these "p-prims", or phenomenological primitives, and uses them to reorganize and exploit the construction of scientific conceptions [26]. An example of a p-prim in physics is when you induce motion; it eventually stops after a certain amount of time. As they learn, these p-primes are incorporated into more complex explanatory systems, which can give them a new dimension. Learners might then realize that a certain piece of knowledge, once integrated into a larger system, does not always work and only applies in special cases as an exception [24].

DiSessa emphasizes causal meaning that is closely linked to concept development and problem solving, rather than focusing solely on concept development or problem solving. He adds that, for deep and real learning, the teacher must teach the same causal relationships repeatedly in a variety of contexts, focusing on a limited selection of concepts [1]. This model differs from Posner and Giordan's in that it does not make cognitive conflict a fundamental principle [28]. It is more relevant when applied to domains rich in observable phenomena and directly linked to experience. This may explain why its application to fields other than mechanics has not been as convincing. In the context of conceptual change, DiSessa's model therefore occupies a relatively restricted [27] position.

2.2.4. Vosniadou's Model (1994)

According to Vosniadou, conceptual change implies a revision of both the general framework and specific concepts [1]. In other words, it is not simply an instantaneous and spontaneous transformation of conceptions from one theoretical framework to another over a short period [24]. These initial conceptions, called "naive conceptions", according to Vosniadou, are formed during childhood and include ontological presuppositions. When this naïve framework conflicts with the knowledge acquired through education or experience, the learner attempts to assimilate the information in such a way as to make it compatible with this framework.

To gradually resolve the instability caused by these contradictions in the learner's mental models and achieve conceptual change, it is necessary to revise the learner's assumptions [28]. In his model, Vosniadou proposes various ideas for effective learning. He points out that it is difficult to transfer knowledge acquired at school to everyday situations, but that the opposite problem does not arise [24]. Therefore, he encourages teachers to take learners' presuppositions and beliefs into account when designing the teaching sequence. Sometimes, it is necessary to teach more complex concepts than simpler ones in order to facilitate learning [1].

Vosniadou suggests various approaches to facilitating the learning process for learners. These include giving learners' problems to solve and providing them with materials to manipulate so that they can express their mental models. In addition, it encourages learners to debate and discuss among themselves, which helps them become aware of their mental models and the concepts involved. It also gives them opportunities to compare their explanations with those of experts and with reality. Finally, he recommends planning activities that encourage learners to organize their knowledge. Discussion plays an important role in the process of conceptual change, as it enables learners to understand the need for a profound revision of their beliefs and prompts them to engage consciously and deliberately in the revision necessary for conceptual change [1]. All these models offer different perspectives on the process of conceptual change and can be used as guides for designing pedagogical interventions aimed at correcting conceptions and fostering a better understanding of scientific concepts.

2.3. Conceptions

The subject of representations has been the subject of reflection and research since the 1970s [2]. Derived from sociology, it is one of the first concepts developed by science didactics. In fact, the concept of representations is polysemous, taking on several meanings depending on the scientific field to which it belongs. That is why didacticisms Andre Giordan and Gérard de Vecchi [8] have proposed using the term conception instead of representation to refer to erroneous knowledge and common sense.

2.3.1. What is the Conception?

Most of the studies that have been carried out on the subject of conceptions have been aimed at analyzing the conceptions that learners may have of different scientific concepts [12]. These conceptions, which are generally surprising, influence learners' understanding and their learning process as they seek to harmonize new information with what they already believe to be true. For Astolfi [13], the notion of conception is synonymous with learners' alternative representations. She emphasizes that these conceptions encompass both pre-existing ideas stored in long-term memory [13]. These conceptions, according to Giordan [14], are formed from external elements and are selectively retained information. They are dissociated from the initial context and used to construct new knowledge. Even before learning begins, the learner is not devoid of all conception. In general, he or she already has a mental conception, often incorrect, of what he or she is about to study. However, when he receives information or analyzes a concept, the learner does so use his own set of conceptions [15].

Thus, the conception is a set of ideas and of information that learners make of the world around them, and this can come from very varied sources, such as television shows, statements from parents or friends, their own imagination, or even created by teaching - same, let us cite for example the idea that a ray of light can be seen from the side [16]. To construct scientific knowledge, it is necessary to take into account the learner's initial conceptions, correct them in the event of error, and avoid learning obstacles. This often involves a paradigm or perspective shift, where the learner has to question old beliefs or patterns of thinking in order to adopt new ways of doing and understanding. This is why it is necessary to study the conditions and methods of this change [2].

2.3.2. The Characteristics and Functions of Conceptions

The learner mobilizes conceptions to understand, explain, and interpret the world around him or her and to solve everyday problems; these conceptions present a form of reading grid [10, 11].

According to Giordan [8], several features characterize conceptions:

- Variability: the great diversity of conceptions.
- Coexistence: the possibility of several conceptions coexisting at the same time without conflicting with each other or with institutional knowledge.
- Evolution: the possibility of evolution through the integration of new levels of elements.
- Resistance: its resistance to the teaching of scientific concepts, especially classical education.

3. RESEARCH METHODOLOGY

In this study, we adopted the case study method to answer our problematic question. To this end, we designed a didactic device for conceptual change based on Vosniadou's model [1]. This device was experimented with by four Moroccan physics-chemistry teachers in the junior high school cycle. The study device was tested in four first-year secondary school classes, each comprising 30 learners at a homogeneous academic level. The study was organized into four phases:

3.1. Device Design Phase

The study device comprises a theoretical input on conceptual change, a pre-test, three experimental investigation activities, and a post-test. The theoretical input is an opportunity for the four teachers to familiarize themselves with the concept of conceptual change and its various models. The pre-test used is a three-item situation-problem, with each item linked to an electrical prerequisite. The pre-test aims to identify learners' misconceptions about electricity, related to the direction of electric current in a circuit, types of electrical assembly, and the intensity of electric current. This problem situation is designed according to the criteria mentioned by Robardet [15]: it is real, authentic, and presents a challenge to the learner. This challenge creates a cognitive imbalance in the learner, requiring him or her to mobilize prior knowledge and conceptions.

The investigative activities proposed are remediation activities based on initial problem situations that create a cognitive conflict in learners, prompting them to rethink their erroneous conceptions and seek scientific alternatives by solving the problem situations through experimental trial and error. The post-test used is a problem situation of the same family as the situation used in the pre-test, and also covers the same concepts as the first (the direction of electric current in a circuit type of electrical assembly - the intensity of electric current). The aim of the post-test is to assess the learners' newly acquired skills in order to measure the effect of using the conceptual change device.

3.2. The Device Validation Phase

The proposed conceptual change device was designed by a team of science didactics researchers. The device was validated first by several didactic experts and second by a pre-test involving 20 volunteer learners. This validation process led to several modifications and improvements.

3.3. The Device Experimentation Phase

To achieve our research objective, the teachers first benefited from theoretical training on the themes of conceptual change and conceptions. Secondly, the teachers experimented with the didactic device. This experimentation took place over three sessions, each lasting one hour. In the first session (pre-test phase), the teacher presented each learner with an assessment in the form of an electrical problem situation. By analyzing the learners' productions in relation to the objectives set, the teacher identifies the various obstacles that may stand in the way of learning electricity concepts.

In the second session (the investigation phase), once the obstacles have been identified, the teacher guides each learner through the process of overcoming them. To do this, he divides the learners into groups according to their needs (conception-obstacle). Faced with the initial problem-situation proposed in the experimental investigation activity, learners are encouraged to check the validity of their erroneous conceptions by proposing hypotheses for this initial situation and verifying these hypotheses through experimental trial and error. Each group of learners is provided with the equipment needed to carry out the experiment appropriate to each proposed hypothesis. In the third session (post-test phase), the teacher proposes a new problem situation of the same family as the first to each learner in order to assess the new knowledge acquired and check the effectiveness of the proposed system in remedying conceptions and overcoming learning obstacles.

3.4. The Device Evaluation Phase

The evaluation of the proposed conceptual change device is carried out by comparing the initial state of learning with the final state of learning. This comparison is based on a graphical method, which consists of graphically representing the learners' responses to each state (initial and final). With this in mind, and in order to guide the analysis of the data in this study and verify the basic hypothesis, we formulate the following sub-hypotheses:

- H_0: There is no significant difference between the initial teaching-learning state and the final learning state.
- H_1: There is a significant difference between the initial teaching-learning state and the final learning state.

4. RESULTS AND DISCUSSION

4.1. Pre-Test Results

4.1.1. The First Question

This question concerns learners' ability to determine the direction of current in an electric circuit.

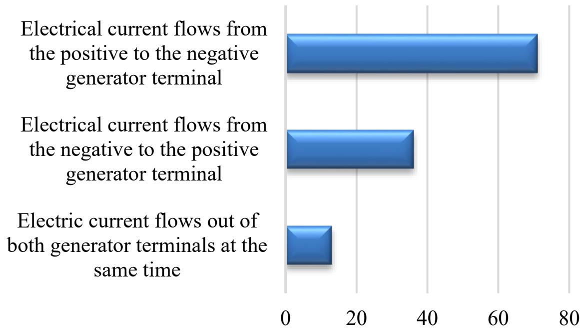

Figure 1. Learners' answers to question 1

A significant proportion of learners (59%) answered that the electric current flows from the positive terminal of the generator to the negative terminal. However, for the remaining two categories, they were unable to determine the correct direction of the current; in such a way, 30% of learners confused the positive and negative poles of the generator, and 11% of learners thought that a positive current joins a negative current to give energy, i.e., the antagonistic conception of current [17]. Faced with this difficulty, and in order to remedy the conceptions behind it, each teacher asks his or her learners to make a model of a simple electrical circuit containing a generator, a diode and, a lamp in order to determine and specify for themselves, through experimental trial and error, the direction of the electric current in the electrical circuit constructed.

4.1.2. The Second Question

The second question focuses on the learners' ability to differentiate and diagram the two types of electrical circuits (series and parallel). The teacher asks each learner to draw a series circuit containing a voltage generator and two lamps.

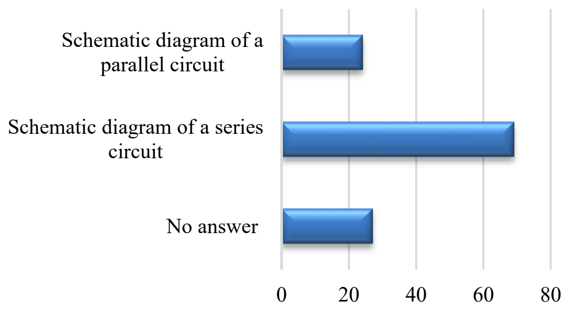

Figure 2. Learners' answers to question 2

More than half the learners (58%) were able to draw the circuit correctly, i.e., the generator and the two lamps in the same loop (series circuit). On the other hand, 20% of learners drew the two lamps in a shunt circuit (these learners confused the series and shunt circuits), and the remaining 22% were unable to provide an answer. To overcome this difficulty and the conception behind it, the teacher sets up two circuit models, one in series and the other in shunt, and asks the learners to determine and distinguish the characteristics of the two types of circuits in terms of electrical voltage and current intensity.

4.1.3. The Third Question

The third question concerns learners' ability to give and predict the value of electric current intensity at different points in an electric circuit.

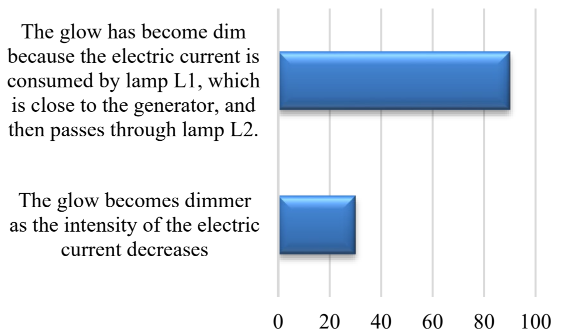

Figure 3. Learners' answers to question 3

A large proportion of learners (75%) gave incorrect answers about the value of the electric current at different points in the series circuit. They found that the current leaves the generator and passes through the nearest lamp; this lamp L_1 consumes the current, and the rest passes through lamp L_2 until the current runs out, hence the intensity decreases in the circuit; in fact, this is an anthropocentric view of current [17]. Works [19] have shed light on this conception and classified it as a didactic obstacle stemming from teaching by analogy. Learners consider that electric current behaves in the same way as water current. To overcome this didactic obstacle and remedy the conception behind it, each teacher suggests that his learners measure the intensity of electric current in a series circuit, using an ammeter at several points in the electrical circuit, then compare the values obtained and formulate a proposal concerning the intensity of electric current in a series circuit.

4.2. Post-Test Results and Evaluation of Proposed Remedial Strategies

In order to evaluate the proposed conceptual change didactic device, we compared the results of the initial state (the pre-test) with those of the final state (the post-test). This comparison is illustrated in Figure 4.

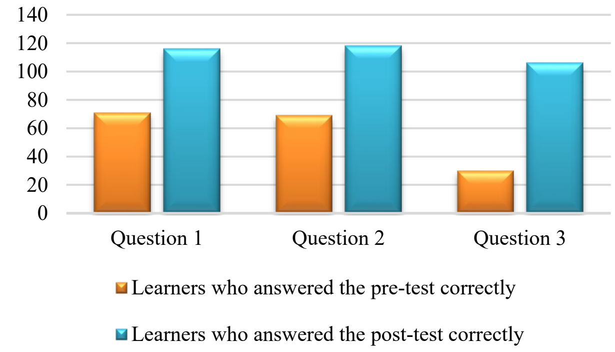

Figure 4. Comparison of learners' responses in the initial state with those in the final state

According to the result of the comparison between the two states (initial and final) in the three cases presented in figure 4, we note an improvement in terms of the number of correct answers, with a gain of 45 units in the first case (question 1), 49 units in the second case (question 2), and 76 units in the last case (question 3). This improvement is due to the remediation strategies used by the teachers. These strategies led to a conceptual change based on cognitive and socio-cognitive conflicts, guided by investigative activities and experimental trial and error. In the first case (question 1), 116 learners were able to overcome the obstacle mentioned in this question and were able to understand the role of each generator pole and successfully determine the correct direction of the electric current.

In the second case (question 2), 118 learners overcame the difficulty mentioned in this question by distinguishing the type of electrical circuit required by understanding its properties in terms of current intensity and voltage. In the last case (question 3), 106 learners were able to overcome the obstacle mentioned in this question by predicting the electric current intensity at several different points of a series electric circuit by mobilizing the law of uniqueness of intensities. Analysis of the results discussed shows that there is a significant and positive improvement between the initial teaching-learning state and the final state, which leads us to reject the null hypothesis H_0 and retain the alternative hypothesis H_1, thereby validating the general hypothesis and answering the research question.

5. CONCLUSION AND PROSPECTS

The aim of this project was to implement and test a didactic device for conceptual change in electricity. The device consists of a theoretical contribution on conceptual change, its contribution to the development of teaching and learning quality, a pre-test, three experimental investigation activities, and a post-test. The results of this work demonstrated the effectiveness of the proposed conceptual change didactic device in improving the quality of learning in relation to electricity in secondary school.

The improvement in teaching-learning quality recorded is due to several elements, including the proposed remediation strategies based on investigation, cognitive and socio-cognitive conflicts within working groups, and learner-guided experimental trial and error. Nevertheless, this improvement did not reach 100% in terms of the number of learners benefiting, which could be explained by the lack and non-mastery of prerequisites related to electricity in secondary school, which required in-depth remediation of these prerequisites. This work has shown the need to consider learners' conceptions during the teaching-learning process in order to use conceptual change as a remediation practice. With this in mind, we aim to design a number of conceptual change didactic devices covering the different fields of physics and chemistry in college and qualifying secondary cycles.

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