International Journal of Learning Spaces Studies, 2023. 2(1): 29-43.

The International Journal of Learning Spaces Studies (IJLSS)

*Homepage: https://journals.artahub.com/*

ORIGINAL RESEARCH ARTICLE

# Designing the Educational Model in Chemistry Education

**Javad Hatami[1], Fariba Ansarimoghadam[2*], Atiyeh Seidi[3], Mehrnaz Gohari[4]**

[1] *Professor in Educational Technology, Faculty of Humanities, Tarbiat Modares University, Tehran, Iran. j.hatami@modares.ac.ir, 0000-0002-4517-2039*
[2] *PhD Candidate in Education Technology, Faculty of Humanities, Tarbiat Modares University, Tehran, Iran. (Corresponding Author) faribaansari368@gmail.com, 0000-0002-0630-7287*
[3] *MA. of Physical Chemistry, University of Science and Technology, Tehran, Iran. atiyeseidi@yahoo.com*
[4] *PhD Candidate in Education Technology, Faculty of Humanities, Tarbiat Modares University, Tehran, Iran. Mehrnaz.gohari@yahoo.com*

## ARTICLE INFO

***Article History:***
Received: 2022/12/29
Revised: 2023/02/02
Accepted: 2023/03/06
Published Online: 2023/03/28

***Keywords:***
Battery,
Educational Chemistry Model,
Educational Model,
Electrochemistry.

*Number of Reference:* 59
*Number of Figures:* 4
*Number of Tables:* 8

***DOI:***

Publisher:
Ayande Amoozan -e- ATA (AAA)

## ABSTRACT

**Purpose**: This study aims to design a Zn-Air Battery Educational Model and assess its impact on Student Learning.

**Method**: This research employs a quantitative approach and a Quasi-Experimental Methodology. According to the new Modeling Methods in Chemistry Education and based on the background investigation and Content Analysis of previous Research, a simple educational model of the battery was designed using readily available and inexpensive materials. This study first examined the characteristics of Zn-Air battery construction, besides the special materials and required conditions before describing the training model for this battery. Then, students were divided randomly into experimental and control groups using Solomon's Four-Group Research Design including four groups of sixty individuals. In the experimental group, the 5E Method was used to create a structured modeling environment in which students could create their desired models, and its validity was confirmed by the researcher. Cronbach's alpha was used to determine its reliability. The Research hypotheses were examined and analyzed using the analysis of variance test and the two-sided independent t-test in the section on inferential statistics. For Data Analysis and Statistical Error Reduction, SPSS was utilized.

**Findings**: The Findings revealed that the experimental group learned significantly more than the control group students and performed better.

**Conclusion**: learning with the model makes learning more durable because the learner organizes his own learning and knows when and how to obtain it. The inductive nature of the model aids students in gaining a deeper understanding of the key concepts through the examination of natural phenomena and events used in the research.

►**Citation:** Hatami, J., Ansarimoghadam, F., Seidi, A., & Gohari, M. (2023). Designing the Educational Model in Chemistry Education. *The International Journal of Learning Space Studies(IJLSS),* 2(1): 29-43.

## Introduction

Science education has occupied a prominent position in society's curricula for a long time and has always been the focus of education experts. Due to the effects of information technology, science education processes have evolved in the 21st century (Chuwong & Vrapon, 2021).

Learning chemistry is a part of learning science that is important in studying the phenomena that exist in nature (Elhan, 2016). Over the past decades, a significant body of literature has emerged on the benefits of visualizations to enhance chemistry learning (Wu et al., 2001; Tasker & Dalton, 2006; Chang & Linn, 2013; Akaygun, 2016; Kelly et al., 2017).

The concept of chemistry as a life-centered science includes processes that size and number are not directly observed on a scale of the daily human experience. (Davenport & Rafti, 2018). Relatively little time is available for the study of an extensive body of knowledge, resulting in teacher-centered learning dominating the classroom. Students have little opportunity to do experiments or solve problems (Orosz et al.2022). A high level of visualization is required to comprehend chemistry (Al-Balushi, 2013; Al-Balushi & Cole, 2013; Barak & Dari, 2011).

On the one hand, many abstract and non-intuitive concepts must be learned in chemistry and other sciences. On the other hand, the identification of many pieces of evidence indicating the educational problems of students has led chemists to divide this essential science into three levels: the macroscopic level (where the senses are caught - showing matter and observing changes in the matter during the experiment), the submicroscopic level showing what is observed on the submicroscopic level, and the symbolic level Abstracts chemical phenomena using chemical symbols, formulas, expressions and equations (Johnston, 1982; Gilbert & Tergest, 2009; Talanker, 2011; Townes et al., 2012).

Using these levels as methods of representation facilitates student learning, makes it simpler to interpret a concept, and fosters a deeper understanding of chemical systems (Ainsworth, 2007). Conceptual chemistry knowledge includes the ability to represent and interpret chemistry problems using these levels (De Jong and Tergest, 2002; Osman and Lee, 2013). According to Johnston (1999), the submicroscopic and macroscopic levels are rarely emphasized in the majority of chemistry courses. Multiple studies support the notion that describing and visualizing the relationship between macroscopic and submicroscopic phenomena is a source of difficulty for many students in learning chemistry (Johnston, 1999).

Without the conceptual and graphical connection between these three levels, it may be difficult for students to comprehend chemistry concepts (Wu & Shah, 2004). In fact, the student’s ability to comprehend the function of each level of chemical representations and to move from one level to the next has a significant impact on the clarity of their explanations. However, students often find it confusing to comprehend and use the Interaction between these levels. (Gilbert & Tergest, 2009). Lack of macroscopic experience (Nelson, 2002), misconceptions of the submicroscopic nature of matter (Harrison & Tergest, 2002), failure to use complex conventions at the symbolic level (Marais & Jordan, 2000), and the inability to move between levels are some of the consequences of the issue has been raised (Gable, 1999).

The inability to move between levels poses a challenge in chemistry education, particularly in creating a bridge between understanding abstract and concrete concepts; where students place their experiences in developing hypotheses at the submicroscopic and symbolic levels (Driver & Erickson, 1983; Gable, 1999; Adba, 2012). In contrast, many abstract chemistry concepts necessitate three-dimensional thinking and the capacity to visualize, comprehend, and conceptualize the content. The inability of students to correctly visualize is one of the obstacles to understanding chemistry (Gabel et al., 2013). The goal of chemistry education is to establish scientific literacy and teach the reasoning and inquiry skills needed for success in everyday life, such as data collection and analysis, evidence-based decision-making, and cooperation (Orosez et al, 2022).

### *Teaching Electrochemistry*

Electrochemistry is a branch of physical and analytical chemistry that studies the movement of electrons in an oxidation or reduction reaction that either leads to the production of electricity or the occurrence of a chemical reaction. Oxidation-Reduction reactions involve an alteration in the oxidation number of elements and are obtained by summing up two half-reactions. A reduction half-reaction occurs when the oxidation number of an element decreases, while an oxidation half-reaction occurs when the oxidation number of an element increases (Farshadi, 2012). It can be asserted that all electrochemical reactions belong to the oxidation-reduction category; consequently, electron transfer is regarded as an essential component of these reactions. Reactions such as Iron rusting and food spoilage are considered harmful oxidation-reduction reactions, whereas metal plating and combustion are considered beneficial oxidation-reduction reactions (Ebbing and Gamo, 2009).

The significance of electrochemistry cannot be denied. Electrochemistry has a crucial role in a wide/variety of technological applications. Although electrochemistry is ubiquitous, there is very little formal instruction on the subject. Energy production and storage is a fundamental topic in electrochemistry. Batteries are devices that store or convert human-required energy. Batteries are not only used to store energy for mobile devices and vehicles, but they can also be a relatively viable substitute for renewable and nonrenewable energy sources. Electrochemistry is a key concept in teaching and learning chemistry, with considerable and significant applications.

The zinc-air battery is one of the more commonly used batteries in the industrial and technological sectors. These batteries are regarded as energy storage tanks, and significant progress has been made to increase their capacity and improve them over the years. Besides having a high capacity, zinc-air batteries are inexpensive. In addition to these benefits, high security and biocompatibility have contributed to the superiority of these batteries. According to electrochemical theories, these batteries have a capacity of up to 1,350 Wh/kg. This capacity has a special energy requirement of 200 Wh/kg. Among the significant applications of this battery type, we can name the aviation industry, the rail industry, and the medical industry, among others. These batteries can be made and modeled with readily available and simple tools. First, the components of the real environment are selected for modeling, and then, based on the intended purpose, characteristics are abstracted from each real component. In other words, for each component of the real environment, an abstract entity is created, and the real environment is modeled among the abstract entities by establishing a connection similar to the connection between the real components.

### *Models in Teaching*

Creating models that evoke an image of the subject being taught within the student's mind is an effective method for teaching experimental courses such as chemistry. By designing an appropriate model, it is possible to teach topics in chemistry, such as electrochemistry, that cannot be taught without an example.

A model is a representation of reality that expresses the most essential characteristics of the real world in a straightforward and general manner. Not the entirety of reality, but a useful and comprehensible portion of it, can be comprehended with the aid of models. In this regard, models are essential because they allow one to comprehend how a system behaves.

Consider the following to explain the performance of a model:

-The capacity to comprehend complicated phenomena by simplifying them on a smaller scale

-Offering a structure for defining, collecting, editing, or processing data

-Organization and categorization of vast quantities of data

-Explanation of how a phenomenon takes place

-Comparing one process against another

Students can manipulate experimental variables and generate results that can be predicted and visualized through the use of models (De Jong & van Julingen, 1998; Rutten et al., 2012). While modeling, students choose a specific feature to concentrate their efforts on.

Using models in the learning process offers numerous benefits. Here are some of these advantages.

Models can be created in class with student participation.

The models can be opened and closed so that students can learn about the model's components.

Models allow for a more accurate depiction of an object's essential characteristics.

Students can be shown objects and their functions regardless of the complexity of their appearance by using models.

Students must have tools that allow them to define the objects and variables in the model, as well as tools to specify their behavior to construct models (Luca & Zacharias, 2012; Thies & Wilensky, 2004; Winthrop et al., 2015). In general, modeling-based learning consists of two components, as depicted in Figure 1: the physical model and the computer-based model.

The term computer-assisted education was coined for the first time in 1960, and it was immediately adopted by education officials and policymakers in various nations for curriculum planning. Currently, the most prevalent uses of computers in educational programs are word processing, data recording and processing, diagram design and creation, modeling, simulation, and Internet research. Using computing software and skills such as programming, it is possible to display abstract concepts (Luka and Zakaria, 2012, Wilinski and Reisman, 2006). Two-dimensional computer animations effectively illustrate the kinetic properties of chemical reactions and phenomena. In the process of education, 3D computer models are utilized to establish relationships. There is substantial literature in the field of supporting science learning through model design using computer-based modeling (Ainsworth et al., 2011, Bullen and Julingen, 2013, Van Juling et al., 2015, Heikhs et al., 2018).

A physical model is a representation of an object or device that can be created on a smaller or larger scale. Using a physical model in teaching, the student begins to physically construct a structure. In the process of making and constructing these structures, there are obstacles, and it is these obstacles that facilitate learning.

In this study, an attempt was made to have students design and construct a physical model of a Zn-Air battery so that they could gain a more concrete understanding of the batteries' macroscopic properties. It is essential to provide students with methods for learning about batteries that are as effective as possible, such as teaching with models and emphasizing the construction and use of appropriate models for learning about batteries.

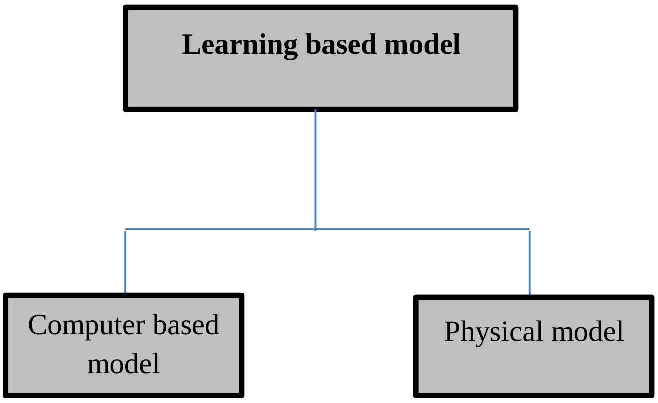

**Figure 1.** Physical model and the computer-based model.

## Literature Review

Numerous researchers are engaged in the design and production of various batteries, as one of the issues raised in this field is the discussion of clean energy and minimizing pollution. However, many students are unaware that the batteries we use every day derive from electrochemistry. They are also unaware that they can design greener and more environmentally friendly batteries using their chemical knowledge. The production of lithium-ion batteries and the introduction of new electrochemical processes for the production of chemicals have made everyone aware of the significance of electrochemistry, and many nations have recognized their deficiencies in electrochemical education (Ciriminna et al., 2022).

Anchalee Chatmontree et al. (2015) introduced a straightforward method for constructing a galvanic cell from a paper-based device. This activity was used as an active learning approach, and teachers were able to use this inexpensive method to introduce students to electrochemistry in the high school laboratory.

In a study conducted by Suyan et al. (2020), a group of volunteer students constructed a battery in a laboratory based on a green field-based experiment to compare to students who experimented using the conventional method. Students in the experimental group demonstrated a greater comprehension of how an electrochemical cell operates and a greater interest in laboratory work, as indicated by the outcome. This group also outperformed the control group in the application of the Nernst equation and benefit-cost-risk reasoning regarding the environmental impacts of batteries.

Education based on exploration has different approaches. Among these approaches, the learning approach is based on modeling - by the student and with support and support from the teacher. Teaching experimental sciences, especially chemistry, requires the understanding of many abstract concepts that if students understand the relationship between these concepts and their tangible results, they will easily solve their problems. Objective tests and models can be used to make these concepts tangible. Since the chemical phenomena in the molecular scale are dynamic but intangible, the use of models helps us in understanding these phenomena. In other words, using models can strengthen the students' visualization of abstract concepts (Buckley, 2004) and help the student to display everything he has in his mind about the phenomenon in question, and directed toward the correct drawing of the mental proposition of the desired concept.

Modeling, the practice of creating models rather than using them, as a learning method; is more effective than other current learning tools in achieving a conceptual and operational understanding of the nature of science and developing reasoning skills (Harrison and Triagast, 2000). Modeling in general means simulating an environment with different sizes from the real environment and possibly using different materials from the materials used in the modeled environment (Grace & Morier, 2002). In modeling, first, the components of the real environment are selected and according to the intended purpose, the characteristics of each of the real components are used. That is, for each of the components of the real environment, an abstract entity is created and by establishing a connection similar to the connection of the real components, the real environment is modeled among the abstract entities. In a review, Luka and Zakaria (2012) showed that model-based learning in science education has a positive effect on cognitive, metacognitive, social, material, and epistemological skills, which in turn helps students learn. One of the effective methods in teaching experimental courses such as chemistry is to make models that evoke an image of the subject being taught in the student's mind. Topics and concepts that cannot be taught in chemistry - the topic of electrochemistry - without providing an example, can be made possible by designing a suitable model. It should be noted that in creating models, a sufficient level of scaffolding is necessary. Without proper scaffolding, students are unable to create models; With very high scaffolds, students may demonstrate reasoning that incorrectly assigns external causes to the model for behavior (Hines et al., 2018). Computer models and simulations allow students to easily manipulate experimental variables and have predictable and easier visualization results (Ratten, 2012).

## Method

In this modeling-based research study, the 5E method was used in the experimental group to create a structured modeling environment in which second-year high school students could create the desired models (Zn -Air). In this environment, the task we assigned the students evaluated at each stage, and their statements and models were recorded and evaluated at each stage as well. we also utilized multimedia-based instruction and an explanation of Zn-Air batteries in the control group.

The participants were selected from girls' and boys' secondary in third-year experimental and mathematical fields. These classes were taught by different teachers. Therefore, to homogenize the initial training in both the control and experimental groups, in the first session of this research, after familiarizing the students with the process, the prerequisite topics were taught again for 20 minutes by the researcher. In all schools, the subject of batteries was already taught once by the respective teacher.

### *The Modeling Task and 5E*

Learners in the experimental group are tasked with designing and constructing a Zn-Air battery model based on the Instructional Design model (5E) (Bybee,2006).

5E model's steps:

#### *1- Engaging*

This step is intended to attract the class's attention to the topic being taught and excite and motivate the students. The teacher may use an intriguing question, a half-written story, a good photograph, a presentation of appropriate scientific activity, etc. to implement this step in teaching about batteries, if environmental facilities are available, we can allow group members to collect batteries from their surroundings within a specified time frame. The children who return to class after this period are enthusiastic and motivated to continue working with the teacher. If such a possibility is not available, the teacher may ask each group to bring a type of battery to class along with his prediction from the previous class, or he may show interesting pictures of various types of batteries or at least use the pictures in the book.

#### *2- Exploration*

At this stage, the instructor asks the groups to observe batteries and pay attention to the types and components. Students use simple, low-risk instruments to observe the constituents of batteries safely. Each group is actively engaged in research and documenting their information on the battery types and components at all times. one of the primary objectives in this stage is developing and enhancing brain and hand coordination while gaining experience. At this stage, the teacher has a guiding role and helps students create an intellectual framework to form new concepts.

#### *3- Explanation*

At this stage, the teacher should give the course of work to the students. The students provide a logical and reasoned explanation for the work and activity performed and describe the observations. A discussion begins between the students. Children try to ask the teacher. But the teacher doesn't answer and tries to find the type of materials used to make batteries by describing the student. Students have obtained information. They found the main components of the battery, made detailed observations, and described their observations.

#### *4- Elaboration*

Since beginning to work with motivation, the children have gained a great deal of knowledge and happiness. They refer to various books, encyclopedias, computer software, etc. The teacher only enlightens the students on how to gather information and solve problems. At this stage, extra / more examples and cases relating to the main concepts of the course are presented, and students are asked to apply what they have learned to generalize to other concepts.

*5- Evaluation*

Continuous evaluation has been started throughout the activity and from the very beginning. The instructor can use an innovative method for the final evaluation. He asks each group to give a comprehensive report on the type, structure, and batteries. Then they report to another group or class to create a battery model based on the description of the batteries in the report. Of course, the more explanations, the more comprehensive the model. For example, if a model does not include an electrolyte battery, the description is incomplete. Self-assessment is even possible, with the group determining how to complete the model based on criteria set by the teacher, such as turning on a light bulb using a student-built battery model. And all this depends on the expectations of the coach and the type of assessment.

### *Instructional Materials and Devices*

The materials used to construct the model are accessible and secure. The list of materials utilized in this study is presented in Table 1:

Table 1. Materials used in this research

| Name of the material | Amount of material |
|---|---|
| Manganese dioxide | 0.4g |
| (MnO2) | 5 drop |
| Potassium hydroxide%84 | 0.2g |
| (KOH) | 1.2g |
| Teflon | 0.2g |
| graphite | 10 drop |
| cellulose | 20 Cm |
| Distilled water | 20 Cm |
| Copper mesh | 1 |

1. Initially, 1.2 grams of graphite, 0.2 grams of cellulose (CMC), 0.2 grams of Teflon (PtFe), and 0.4 grams of manganese (Mn) are combined, followed by the addition of 5 drops of potassium hydroxide (KOH) and thorough mixing to create a paste.
2. A metal net with a diameter of 12 mm was cut in the shape of a circle (because the lid of the used toothpaste is circular), and the prepared paste was placed on it. Figure 2: depicts the cut net used to construct the battery model. Note that the prepared dough should be evenly distributed on the net and cover its entire surface.
3. In the next step, 40 bar pressure was applied to the net and the materials placed on it.
4. Finally, the prepared electrode was then heated in an oven for two hours at 200 degrees Celsius. A manufactured example of an electrode is depicted in Figure 3.

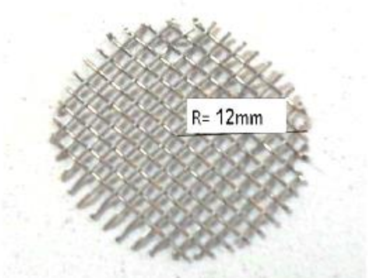

**Figure 2.** Cut-out mesh to make zinc-air battery model

**Figure 3.** An example of an electrode made for a zinc-air battery model

1. First, a thin copper wire was threaded through a hole drilled in the toothpaste cap.
2. Cutting the copper mesh to the size of the toothpaste cap with scissors, connecting it to a thin copper wire, and inserting it into the plastic cap.
3. The gap in the toothpaste cap was sealed with glue to prevent air from passing through.
4. The manufactured electrode is placed inside the toothpaste cap.
5. In the next step, a filter paper was cut to the size of the electrode and placed on the surface of the electrode, which has been moistened with a few drops of water.
6. The gel mixture containing zinc was extracted from a shattered alkaline battery and placed on filter paper. Spread the aforementioned mixture evenly on filter paper.

Note: It should be noted that discharged zinc should not be exposed to air for an extended period of time, as it dries and loses its gel state when exposed to air.

7. The metal mesh cut again to fit the toothpaste cap. On top of the zinc-containing mixture, a wire made from the same mesh as the net was attached.
8. After removing the adhesive from the cathode, the battery begins functioning. This battery's voltage is approximately 2 volts, making it suitable for powering an LED lamp.

In the following figure, the steps for constructing a zinc-air battery model are depicted graphically Figure 4.

### *Research implementation method*

The research design used in this study is a type of experimental design with pre-test and post-test, and Solomon's four-group design used to eliminate the effect of the pre-test. For this purpose, all people divided into four groups. This design enables the researcher to perform several statistical analyzes and provide more reliable data. Solomon's four-group design is shown in the following Table 2:

**Table 2.** Solomon’s four-group design

| Groups | Pre-test | independent variable | Post-test |
|---|---|---|---|
| Experimental group 1 | + | Model-assisted training | + |
| Control group 1 | + | Education in the traditional way (multimedia) | + |
| Experimental group 2 | - | Model-assisted training | + |
| Control group 2 | - | Education in the traditional way (multimedia) | + |

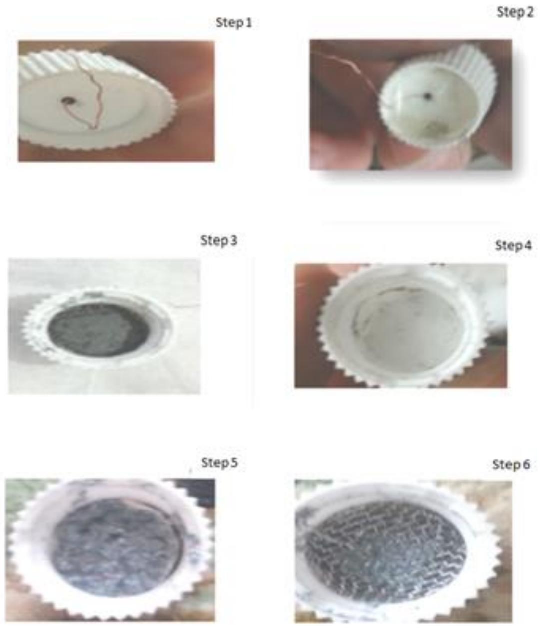

**Figure 4.** steps of making zinc-air battery model schematically

### *Teaching in the Experimental and Control Groups*

In this study, students participated in two experimental and control groups to learn electrochemistry. The experimental model was used to instruct the learners in the experimental groups. In contrast, the students in the control group received instruction according to the standard curriculum (using multimedia-assisted education). Regarding the method of conducting the research, a written and regular program developed in advance, and it carried out as follows, taking into account all undesirable factors and variables that could affect its execution:

- *Pre-test step*

In the control and experimental groups, learners without prior knowledge of the desired topics gave a pre-test to establish a baseline for post-test comparison. In this study's pre-test, standard questions utilized. The pre-test questions were formatted as a description of the educational materials, consistent with the intended topic, and scored on a 10-point scale. To determine the level of formal and content validity of the knowledge learning test, six chemistry teachers with teaching experience given the questions. After receiving their feedback, the necessary adjustments made.

- *Teaching in the control group*

In the control group, learning and explanation were conducted electronically and in a multimedia format. First, an explanation of electrochemistry was provided, followed by the introduction of electrochemical cells. Then, the types of batteries were described, as well as the zinc-air battery's place and function in daily life and industry, and the chemical reactions that occur in this battery. After instruction, the teacher asked one or more questions to which the students responded.

- *Teaching in experimental groups*

Students were divided into 4 groups. At first, brief explanations about electrochemistry were presented, questions about batteries were asked, and students were asked to answer the questions in groups. Then the students were engaged in building and designing the model using the 5E method. The coach served as a guide. During battery construction, the instructor often asked the following questions:

Why do you think zinc was used to make this battery?

- What other inexpensive household items can be used to make this battery?
- In your opinion, what feature of this battery distinguishes it from the batteries used in household appliances?

The teacher's stimulating questions create a meaningful challenge for the students so that each student strives to ask a question related to the stimulating question posed. At the conclusion of the battery-making process, each group's leader was required to explain the battery-making procedure to the class.

*- Post-test stage*

At the end, the final test was taken from students in both control and experimental groups. Teacher-made questions were used in the post-test. The pre-test and post-test questions were prepared in the form of a description of the educational materials, in line with the subject of the course and with a 10-point scale. To collect data, researcher-made (descriptive) tests were used.

The questions of the post-test stage were:

1. Write the reactions carried out inside the zinc-air battery (in both the reduction half-reaction and the oxidation half-reaction).
2. Name the electrolyte used in the manufactured battery? What other materials can we use as electrolyte in this battery?
3. What is the role of the filter paper used in this battery? Introduce an alternative to filter paper in this battery?
4. What is the use of zinc-air batteries in household and industrial appliances?
5. What do you suggest to increase the voltage in zinc-air battery?
6. In your opinion, what are the disadvantages and advantages of the manufactured battery compared to other batteries?

## Findings

Table 3. shows the dispersion indices of control group 2 (post-test only). And the following values were obtained. The average value of the knowledge post-test of the control group 2 (post-test) is 5.73 and its standard deviation is 2.52.

**Table 3**. Dispersion and centrality indices of control 2group (post-test)

| | **Mean** | **Deviation from the mean** | **Middle** | **Mode** | **The standard deviation** | **Variance** |
|---|---|---|---|---|---|---|
| Post -test Knowledge | 12.73 | 0.15 | 8.08 | 5 | 3.65 | 13.38 |

Table 4 shows the pre-test dispersion indices of the control group 1 and the following values are obtained. The average value of the pre-test knowledge of control group 1 (pre-post-test) is 3.95 and its standard deviation is 2.07, and the average value of the post-test knowledge of control group 1 (pre-post-test) is 5.98 and its standard deviation is 2.56.

**Table 4.** Dispersion and centrality indices of the control group (pre-test and post-test)

| | **Mean** | **Deviation from the mean** | **Middle** | **Mode** | **The standard deviation** | **variance** |
|---|---|---|---|---|---|---|
| **Pre -test** | 11.95 | 0.15 | 3.5 | 3 | 2.07 | 4.32 |
| **post -test** | 12.98 | 0.10 | 5.3 | 3 | 2.56 | 6.57 |
| **Knowledge growth** | 1.03 | 0.37 | 0.5 | 0.5 | 2.07 | 2.52 |

In the table 5, the findings of the control group were tested using analysis of variance (ANOVA) and the results confirmed the significance of the findings. The results of this type of classification are shown in the above table. The significance level of zero indicates that the null hypothesis (the equality of the average knowledge of the control group) is rejected, and therefore the researcher's hypothesis can be confirmed according to this statistic. And also the F statistic in this section shows the fact that the inter-group variance is 25.8 times higher than the intra-group variance.

**Table 5**. Analysis of variance test (ANOVA) in the entire control group

| ANOVA | | | | | |
|---|---|---|---|---|---|
| | sum of squares | Degrees of freedom | average of squares | F | Meaningful level |
| Between groups | 324.5 | 3 | 182.5 | 81.6 | 0.000 |
| Intergroup | 108.09 | 61 | 4.02 | | |
| Total | 432/59 | 64 | | | |

**Table 6.** Dispersion and centrality indices of experiment group2 (post-test)

| | Mean | Deviation from the mean | Middle | Mode | The standard deviation | Variance |
|---|---|---|---|---|---|---|
| Post -test Knowledge | 14.98 | 0.15 | 13.34 | 0 | 3.91 | 15.35 |

**Table 7.** Dispersion and centrality indices of the experiment1 group (pre-test and post-test)

| | Mean | Deviation from the mean | Middle | Mode | The standard deviation | variance |
|---|---|---|---|---|---|---|
| Post -test Knowledge | 11.89 | 0.17 | 11.44 | 6 | 3.49 | 12.23 |
| Pre -test | 15.12 | 0.10 | 12.87 | 10 | 3.97 | 15.83 |
| Knowledge growth | 3.33 | 0.12 | 5.01 | 5.5 | 2.41 | 1.81 |

**Table 8.** Analysis of variance test (ANOVA) in the entire experiment group

| ANOVA | | | | | |
|---|---|---|---|---|---|
| | sum of squares | Degrees of freedom | average of squares | F | Meaningful level |
| Between groups | 378.9 | 4 | 305.09 | 52.1 | 0.000 |
| Intergroup | 114. 7 | 46 | 2.78 | | |
| Total | 493.6 | 50 | | | |

In the table8, the findings of test group 1 were tested using ANOVA and the results confirmed the significance of the findings. The results of this type of classification are shown in the above table. The significance level of zero indicates that the null hypothesis (the equality of the average knowledge of the control group) is rejected, and therefore the researcher's hypothesis can be confirmed according to this statistic. And also the F statistic in this section shows the fact that the inter-group variance is 52.01 times higher than the intra-group variance.

### *Comparison of knowledge growth in control and experimental groups*

For this comparison, the difference between pre- and post-test scores was used. As a result, we were only able to examine groups that had both the pre- and post-tests; control 1 and experiment 1 were utilized. According to descriptive and significant statistics, the amount of knowledge growth of control group 1 (pre- and post-test) was 1. 03 and the amount of knowledge growth of experimental group 1 (pre- and post-test) was 3.33. Using descriptive statistics, the difference between the average difference between the pre- and post-tests of the control group 1 (with pre-test) and experiment 1 (with pre-test) suggests that the model-based teaching method increases knowledge and improves the quality of students' learning.

## Discussion

The results indicate that the learning of students trained with the model differs significantly from students trained with the common teaching method. In other words, the difference between the mean post-test scores of the control and experimental groups is statistically significant. There is a significant difference in the learning of the knowledge field in the chemistry course between the control and experimental groups of third-year students in high school. In other words, the students who learned the concepts and applications of electrochemical cells using the model, compared to the students who received the same training with the conventional (multimedia) method, gained more knowledge. The mean difference on the post-test demonstrates the effect of the model on the students' comprehension of abstract concepts. At the molecular level, electrochemistry concepts are dynamic but intangible. In this investigation, the application of the model has enhanced the students' learning and comprehension of electrochemical concepts. In fact, students' capacity to comprehend the function of each level of chemical representations and to progress from one level to the next has increased. On the other hand, the post-test mean scores of the control 2 and experimental 2 groups for knowledge learning were 12.73 and 14.98, respectively, which is statistically significant. This mean increase indicates that the teaching method incorporating the model has resulted in a significant increase in students' knowledge of electrochemical cells, and that model enables students to conduct mental explorations at the molecular level. In addition, the students of experimental group 2 who were trained with the model had a more exploratory mindset than the students of control group 2 who were trained in the conventional multimedia manner.

On the other hand, the difference between the means of the knowledge post-tests of the control 1 and experiment 1 groups is significant; this indicates that there is a significant difference in the learning of chemistry in the subject of electrochemical cells between the control 1 and experiment 1 groups. In other words, students taught using the model demonstrate greater academic achievement than students taught using the conventional method. The use of the model has improved the student’s comprehension of the phenomena investigated in this study.

On the other hand, the data indicate that the mean post-test knowledge of the two groups, control 1 and experiment 1, has increased, indicating an increase in the efficacy of education in using the model. Because the mean of the experimental group 1, which was trained using the model, is higher than the mean of the control group 1, which was trained conventionally; and also because the mean of the post-tests in both the control and experimental groups in group 1 is higher than the mean of the pre-tests in both the control and experimental groups in group 1, but the difference between the mean value of the pre-and post-tests is not statistically significant. The post-test score of group 1's control indicates that conventional teaching of electrochemical cells has a negligible effect on students' knowledge levels. There is a slight difference between the pre-test of the control group 1 and the pre-test of the experimental group 1, which may indicate that the test was administered under the same conditions and at the same time and place as the statistical population of the study. Because the type of choice we had in selecting the schools for the test indicated that the education was identical in every way, it was not unreasonable to anticipate that both groups would have the same mean pre-test score. However, the mean post-test score of experimental group 1 was higher, and this is the reason for the positive and meaningful learning during the implementation of the model, as well as evidence of the suitability of the designed educational model. Also, the difference between the mean of the pre-test and the mean of the post-test Its mean value in the control group 1 and experiment 1 has changed slightly, but there is no significant difference between these means, indicating that the pre-test in this study had no effect. The implementation of the pre-test on the students in this study has not resulted in significant knowledge gains. The majority of the questions on the pre-test were general regarding batteries, whereas the questions on the post-test were specific to Zn-Air batteries.

The mean growth in the knowledge learning score of the two groups of control 1 and experiment 1 is significant. Comparing the pre-test and post-test scores of students in the conventionally trained control group 1 revealed no significant change, indicating that conventional training cannot introduce the world of electrochemistry and the quantity of knowledge visualization. Strengthen students. The electrochemical reactions that occur within batteries cannot exist in the minds of students without a concrete and tangible training. In the experimental group 1, which was trained by the model, the rate of knowledge growth was significantly higher than in the control group 1, indicating that the designed model was able to accurately predict the energy changes and actions that simulate what occurs inside the zinc-air battery and improve students' scientific knowledge.

## Conclusion

Models and modeling are regarded as fundamental components of scientific literacy (Loehner et al., 2005; Luka and Zacharia, 2012; Penner, 2001). The purpose of modeling is for students to repeatedly select the components of a problem or situation, demonstrate their relationships, and evaluate the model using real-world data and experiences. Revise the model in light of new evidence and develop a new model to predict or explain new phenomena (Michel et al., 2015). Instead of being mindless consumers of science and passive learners, students can create scientific representations (Danish & Enidi, 2007) and relate them to their prior knowledge through the use of models (Akaygon & Jones, 2013; Chi, 2009; Rich & Blake, 1994; Zhang and Lin, 2011). This enables them to identify inconsistencies between their ideas and then revise them (Chi, 2009).

In addition to using models, students can experience research in the same or similar ways as many scientists do by building models (Barvey & Roberts, 1999; Frigg & Hartman, 2012; Zhang et al., 2006). This is confirmed by the primary role of models and modeling in the standards for the next generation of scientists (National Research Council, 2013). Students learn to construct concrete representations of abstract concepts and their underlying rationale as they construct models (Windschitel et al., 2008). Yong Kinhui and his colleagues wrote in 2013 that using a model to introduce surface-air batteries to secondary school students through the use of simple tools can increase students' enthusiasm for learning and its vision, thereby fostering innovation in the field of knowledge.

The findings of this study indicate that the use of the model for education results in a significant increase in student learning. In teaching using the model, the learner is placed in a situation where a mental challenge is created for him within the context of the subject; as if the teacher rises the primary motivating question and the students raise secondary questions. Obviously, it is necessary to teach learners a series of prerequisite skills that vary depending on the topic and type of research. During model-based education, students actively construct meaning from the interaction of their prior knowledge with the new information they receive in class from the model, their classmates, and the teacher.

Additionally, learning with the model makes learning more durable because the learner organizes his own learning and knows when and how to obtain it. The inductive nature of the model aids students in gaining a deeper understanding of the key concepts through the examination of natural phenomena and events used in the research. In contrast, the findings of this study indicate that there is a significant difference between the model-based method and the conventional method for the development of learning in the cognitive domain of chemistry and laboratory knowledge. In order to increase the level of knowledge (cognitive learning) based on the activity, the desire and motivation of the learners are examined in an active and attractive environment, and this leads to the development of profound and significant learning. In contrast, the conventional method of using multimedia does not provide conditions for the learner's activity in the classroom.

## Declaration of Competing Interest

The author declares that he has no competing financial interests or known personal relationships that would influence the report presented in this article.

## Reference

Akaygun S., (2016). Is the oxygen atom static or dynamic? The effect of generating animations on students' mental models of atomic structure. *Chemistry Education Research and Practice*, *17*(4), 788-807. https://doi.org/10.1039/C6RP00067C

Akaygun S., Jones L. L., (2014). Words or pictures: A comparison of written and pictorial explanations of physical and chemical equilibria. International Journal of Science Education, 36(5), 783-807. https://doi.org/10.1080/09500693.2013.828361

Andria N. Stammen., Kathy L. Malone., Karen E. Irving., (2018). Effects of Modeling Instruction Professional Development on Biology Teachers' Scientific Reasoning Skills.doi:10.3390/educsci8030119.www.mdpi.com/journal/education. https://doi.org/10.3390/educsci8030119

Arora, P., & Zhang, Z. (2004). Battery separators. *Chemical reviews*, *104*(10), 4419-4462. https://doi.org/10.1021/cr020738u

Chang H.Y., Quintana C., Krajcik J., (2014). Using drawing technology to assess students Visualizations of chemical reaction processes. Journal of Science Education and Technology, 23(3), 355-369. https://doi.org/10.1007/s10956-013-9468-2

Cheng F., and J Chen., (2012). Metal–air batteries: from oxygen reduction electrochemistry to cathode catalysts. Chemical Society Reviews. 41(6): p. 2172-2192. https://doi.org/10.1039/c1cs15228a

Cokelez A., (2012). Junior high school students' ideas about the shape and size of the atom. *Research in Science Education*, *42*(4), 673-686. https://doi.org/10.1007/s11165-011-9223-8

Cooper M. M., Stieff M., DeSutter D., (2017). Sketching the invisible to predict the visible: From drawing to modeling in chemistry. *Topics in cognitive science*, *9*(4), 902-920. https://doi.org/10.1111/tops.12285

Ornek F., (2008). Models in Science Education: Applications of Models in Learning and Teaching Science**,** International Journal of Environmental & Science Education, 2008, 3 (2), 35 – 45ISSN 1306-3065

Gilbert J. K., (2005*)*. Visualization in science education. *Dordrecht: Springer. https://doi.org/10.1007/1-4020-3613-2*

Gilbert J. K., (2010). The role of visual representations in the learning and teaching of science*: An introduction*.

Gilbert J. K., Treagust D. F., (2009a). Introduction: Macro, submicro and symbolic Representations and the relationship between them: Key models in chemical education. Multiple representations in chemical education (pp. 1-8) Dordrecht: Springer. https://doi.org/10.1007/978-1-4020-8872-8_1

Gilbert J. K., Treagust D. F., (2009b). Multiple Representations in Chemical Education (Vol. 4) Dordrecht: Springer Science & Business Media. https://doi.org/10.1007/978-1-4020-8872-8

Hallström, J., & Schönborn, K. J. (2019). Models and modelling for authentic STEM education: reinforcing the argument. *International Journal of STEM Education*, *6*(1), 1-10. https://doi.org/10.1186/s40594-019-0178-z

Harrison, A. G., & Treagust, D. F. (2000a). Learning about atoms, molecules, and chemical bonds: A case study of multiple-model use in grade 11 chemistry. *Science education*, *84*(3), 352-381.https://doi.org/10.1002/(SICI)1098-237X(200005)84:3<352::AID-SCE3>3.0.CO;2-J

Harrison A. G., & Treagust D. F., (2000b). A typology of school science models. *International Journal of Science Education*, 22(9), 1011-1026. https://doi.org/10.1080/095006900416884

Harrison, A. G., & Treagust, D. F. (2002). The particulate nature of matter: Challenges in understanding the submicroscopic world. *Chemical education: Towards research-based practice*, *17*, 189-212. https://doi.org/10.1007/0-306-47977-X_9

Aalto H., (2012). Battery Cell Modeling for Battery Management System. Master's thesis. LUT University.

Hofer E., Abels S. and Lembens A., (2018), Inquiry-based learning and secondary chemistry education – a contradiction? RISTAL, 1(1), 51–65. https://doi.org/10.1515/cti-2018-0030

Horwitz P. (2013). Evolution Is a Model; Why Not Teach It That Way? In D. F. Treagust & C.Y. Tsui (Eds.) multiple representations in biological education (pp. 129-145): Springer. https://doi.org/10.1007/978-94-007-4192-8_8

Jimoyiannis, A., & Komis, V. (2001). Computer simulations in physics teaching and learning: a case study on students' understanding of trajectory motion. *Computers & education*, *36*(2), 183-204. https://doi.org/10.1016/S0360-1315(00)00059-2

Johnstone A. H., (1991). Why is science difficult to learn? Things are seldom what they seem. *Journal of computer assisted learning*, *7*(2), 75-83. https://doi.org/10.1111/j.1365-2729.1991.tb00230.x

Kozma, R., Chin, E., Russell, J., & Marx, N. (2000). The roles of representations and tools in the chemistry laboratory and their implications for chemistry learning. *The Journal of the Learning Sciences*, *9*(2), 105-143. https://doi.org/10.1207/s15327809jls0902_1

Kozma R., & Russell J., (1997). Multimedia and understanding: Expert and novice responses to different representations of chemical phenomena. *Journal of Research in Science Teaching*, 34(9), 949-968. https://doi.org/10.1002/(SICI)1098-2736(199711)34:9<949::AID-TEA7>3.0.CO;2-U

Kozma, R., & Russell, J. (2005). Students becoming chemists: Developing representationl competence. *Visualization in science education*, 121-145. In J. K. Gilbert (Eds.) Visualization in science education (pp. 121-145) Dordrecht: Springer. https://doi.org/10.1007/1-4020-3613-2_8

Lee J.S., et al., (2011). *Metal–air batteries with high energy density: Li–air versus Zn–air*. Advanced Energy Materials. 1(1): p. 34-50. https://doi.org/10.1002/aenm.201000010

Mills R., Tomas L., & Lewthwaite B., (2019). The Impact of Student-Constructed Animation on Middle School Students' Learning about Plate Tectonics. *Journal of Science Education and Technology*, 28(2), 165-177. https://doi.org/10.1007/s10956-018-9755-z

Perkins, D. N., & Grotzer, T. A. (2000). Models and Moves: Focusing on Dimensions of Causal Complexity to Achieve Deeper Scientific Understanding.

Pratt, J. M., Stewart, J. L., Reisner, B. A., Bentley, A. K., Lin, S., Smith, S. R., & Raker, J. R. (2023). Measuring student motivation in foundation-level inorganic chemistry courses: a multi-institution study. *Chemistry Education Research and Practice*, *24*(1), 143-160. https://doi.org/10.1039/D2RP00199C

Smith G. C; Hossain M. M; MacCarthy P., (2012). Why Batteries Deliver a Fairly Constant Voltage until Dead. J. Chem. Educ. 89, 1416. https://doi.org/10.1021/ed200211s

Talanquer V. (2006). Commonsense chemistry: A model for understanding students' Alternative conceptions. *Journal of Chemical Education*, 83(5), 811. https://doi.org/10.1021/ed083p811

Talanquer V. (2007). Explanations and teleology in chemistry education. *International Journal of Science Education*, 29(7), 853-870. *https://doi.org/10.1080/09500690601087632*

Talanquer, V. (2013). When atoms want. *Journal of Chemical Education*, *90*(11), 1419-1424. https://doi.org/10.1021/ed400311x

Talanquer V. (2015). Threshold concepts in chemistry: The critical role of implicit schemas.
*Journal of Chemical Education*, 92(1), 3-9. https://doi.org/10.1021/ed500679k

Yaseen Z., Aubusson P., (2020). Exploring student-generated animations, combined with a representational pedagogy, as a tool for learning in chemistry. Research in Science Education, *50*(2), 529-548. https://doi.org/10.1007/s11165-018-9700-4

Organization for Economic Co-operation and Development. (2014). *What Are Tertiary Students Choosing to Study?* Paris, France: OECD Publishing. Available online: http://www.oecd.org/education/skillsbeyond- school/EDIF%202014--No19.pdf.

Ornek F. (2008) Models in Science Education: Applications of Models in Learning andTeaching Science**.** *International Journal of Environmental & Science Education*, 3 (2), 35 – 45ISSN 1306-3065.

Orosz, G., Németh, V., Kovács, L., Somogyi, Z., & Korom, E. (2023). Guided inquiry-based learning in secondary-school chemistry classes: A case study. *Chemistry Education Research and Practice*, *24*(1), 50-70. https://doi.org/10.1039/D2RP00110A

Özdemir G., Clark D. B., (2007). An Overview of Conceptual Change Theories. *Eurasia Journal of Mathematics, Science & Technology Education*, 3(4). https://doi.org/10.12973/ejmste/75414

Özmen H., (2004). Some student misconceptions in chemistry: A literature review of chemical bonding. *Journal of Science Education and Technology*, 13(2), 147-159. https://doi.org/10.1023/B:JOST.0000031255.92943.6d

Özmen H., (2013). A cross-national review of the studies on the particulate nature of matter and related concepts. *Eurasian Journal of Physics and Chemistry Education*, 5(2).