Educación Química

Didactic sequence for study of enantiomers

Secuencia didáctica para el estudio de enantiómeros

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Resumen

Este artículo presenta un diseño e implementación de una secuencia didáctica (DS) para el estudio de enantiómeros en química. En la DS propuesta, se pensaron diferentes estrategias pedagógicas para alcanzar los objetivos planteados. Estas estrategias pedagógicas de enseñanza y aprendizaje se centraron en la realidad y la enseñanza integrada interdisciplinaria. En este sentido, no sólo se les enseñaron nuevos conceptos, además éstos fueron relacionados con temas de otras materias, tales como, simetría en arte, biología y matemática, dando así significatividad y sentido al estudio de los enantiómeros en química. Entonces, las actividades fueron diseñadas para ir paso a paso en la construcción del conocimiento, siguiendo una dirección adecuada. Las distintas actividades les permitieron a los estudiantes desarrollar y fortalecer diversas habilidades tales como: comprensión lectora, escritura, resolución de situaciones problemáticas y oralidad. Los estudiantes trabajaron y mostraron sus modelos de enantiómeros terminados. Los resultados mostraron un alto nivel de compromiso y motivación por parte de los estudiantes sin perder el interés durante el proceso de aprendizaje.

Palabras clave

Enantiómeros, secuencia didáctica, quiralidad, estrategias pedagógicas, química.

Abstract

This work presents a design and implementation of a didactic sequence (DS) for study of enantiomers in chemistry in high school. In the DS proposed, different pedagogical strategies were thought to achieve the objectives stated. These pedagogical strategies of teaching and learning were focused on reality and interdisciplinary integrated teaching. In this sense, not only were taught new concepts, besides they were related to topic from other subjects, such us symmetry in art, biology and mathematics, thus giving uniqueness and meaning to the study of enantiomers in chemistry. So, the activities were designed to go step by step in the construction of knowledge, following an adequate direction. The different activities allowed the students to develop and strengthen different abilities such as: reading comprehension, writing, solving problematic situations and orality. Students worked and showed their end models of enantiomers. The results showed a high level of dedication and motivation in the part of the students without losing interest during the process.

Keywords

Enantiomers, didactic sequence, chirality, pedagogical strategies, chemistry.

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Introduction

This article presents the use of a Didactic Sequence in the chemistry classroom. A Didactic Sequence is made up of a group of learning activities set in a specific order which considers the progress of the students. It begins with an initial production followed by a series of workshops and finally with a final production (Pardo, Villacañas de Castro, & Ponce, 2013).

For teachers, the design of a DS is also considered regarded an instrument of professional development because it can contribute to the knowledge-based construction of the teacher, thus developing the dimensions of contextual, linguistic, and pedagogical knowledge dimensions of the same (Denardi, 2017).

Considering the importance of planning a DS, a didactic sequence for the study of enantiomers is implemented in a chemistry class for students at the high school. It is important to clarify that usually this topic is not taught in high school due to the complexity that it represents. However, we believe that it is an interesting teaching subject, that has been addressed to allow students to connect chemistry with reality and to make sense of the study of chemistry. So, in high school, teaching the concept of enantiomers will allow them to understand different aspects of their lives.

This work was thought based on the following objectives:

- Expand knowledge of reality from the contribution of chemistry.
- Create an information search plan, stimulating the search and the critical selection of it.
- Achieve the ability to synthesize and communicate the topics studied.
- Promote the autonomy of the student and the role of the teacher as an advisor.
- Reach the ability to connect topics studied in various subjects.
- Learn the basic stereochemistry concepts.
- Observe the spatial distribution of atoms in the molecules, and the superposition or not when chiral centers are present.

In this sense, the selected academic contents were chirality, symmetry, enantiomers and their properties, main chiral molecular structures and racemic mixture.

The planning of the units and the teaching activities of the didactic sequence is detailed in the next sheet.

Phase 1: Presentation of the topic

In the activities to be carried out, the most important question is to provide the students with different tools, which allow them to analyze the reality and previous concepts.

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Activity 1.1

In this activity, the students are proposed to read the following text, divided into groups of no more than two members:

"The mirror has caused amazement to the human spirit since ancient times. The mirror image is attractive to the human mind because it generates the illusion of perfect symmetry. Thus, the mirror is related to the concepts of proportion and measurement and serves as a paradigm for the symmetrical arrangement of the human body (Kuzmina, 2013). In fact, if we look at our right hand in front of a mirror, we can see in it an image corresponding to our left hand. On the other hand, instantly, the mirror decodes a message written with inverted letters. An example of this is the word "ambulance" written on them, which when inverted can be read by the rearview mirror of the car".

Concerning the previous text, it is proposed to students to answer the following questions:

a) What do you understand by "symmetry"?

b) What are the conditions for an object to be symmetrical?

Time allocation for the activity: 40 minutes.

Tasks carried out by the students and evidence of achievement of competencies: reading, orality and writing of answers.

Resources and materials: text, dictionary.

Evidence of learning: delivery of written answer.

Indicators that will be considered for the evaluation: presentation of work in due time, interpretation of the text, clarity of expression in the answers, thoroughness, good writing, and correct spelling.

Activity 1.2

Considering activity 1.1, it is proposed to deepen and expand the concept of symmetry from the perspective of biology. The students, divided into groups of no more than two members, must read the text and solve the activity:

> "In the case of those elements that are not symmetrical, there is no correspondence regarding the shape, dimension, and location of them. An example of this is the case of a lock and its key, both are complementary and the key fits in the lock but if the key does not correspond to that lock there is a case of asymmetry. This "key-lock" model is also used to describe the enzymatic action. Enzymes are protein molecules with intricate and well-defined forms. For selective catalytic activity, an enzyme and the molecule on which it works must adjust to each other, in the same way, that a key must fit into a lock. When the shape of the key matches the spaces of the lock, the lock is opened. If there is any change in the shape, the combination does not work (Kuzmina, 2013)".

Students should work around the following questions:

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a) Describe an asymmetric object that you used to use in daily life.

b) Think of enzymes -asymmetric substances-, and remembering what has been studied in biology, name one of them. You can look for information on the internet if you need.

Time allocation for the activity: 40 minutes.

Tasks performed by students and evidence of achievement of competencies: reading, orality, writing answers.

Resources and materials: text, dictionary, books.

Evidence of learning: written answers to the questions asked.

Indicators that will be considered for the evaluation: presentation of work, interpretation of the text, clarity in the answers, prolixity, articulating knowledge from different fields, and establishing relationships between them and their daily life.

Activity 1.3

This activity proposed to study the concept of symmetry from the perspective of art. The students, divided into groups of no more than two members, must read the text and solve the activity:

"In the study of symmetry, it is necessary to clarify that it is not only an object of analysis in the chemistry and medicine disciplines. In this regard, the famous painter Escher created his own style and caused a great impact on education. Escher used a lot of interesting elements in indoor and outdoor works: such as light, shadow, perspective, and contrast of white and black (as line and tone). Especially his space drawings were very successful. In this space, normal and interrupted perspective works, creating an interesting contrast. The artist aimed to create open and closed spaces in his paintings. In his work called "Night and Day" (Figure 1), the grey and rectangular fields expand upward and become white and blackbirds. Black birds fly to the left and white ones fly to the right. On the left side of the drawing, white birds gather and create a day landscape. On the right side, blackbirds melt down and blend in with the darkness of the night. Day and night scenes are each mirror images of the other (İldeş, 2014).

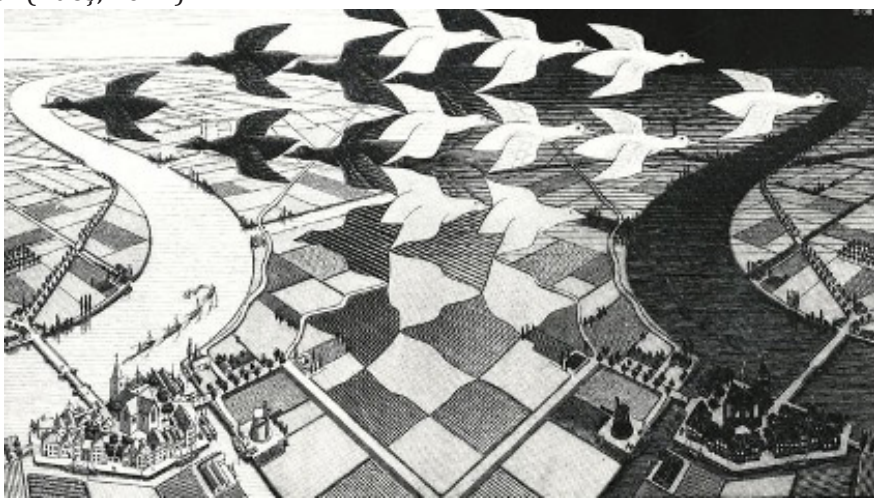

Figure 1. Escher, "Night and Day".

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After reading and observing the image, students must solve the following question:

- Thinking about what you learned in visual arts, did you ever make or see a symmetric image? If you answered yes to the previous question, please describe an explanation for this type of image.
- If your answer is no, research and exemplify an image that meets the symmetry characteristic.

Time allocation for the activity: 40 minutes.

Tasks to be carried out by the students and evidence of achievement of competencies: reading, speaking, writing answers.

Resources and materials: text, dictionary, books, online pages.

Evidence of learning: evaluation of written responses.

Indicators that will be considered for the evaluation: presentation of work, interpretation of the text, clarity, and depth in answers, prolixity, originality, clarity in the answers, ways of articulating knowledge, and the relationship between them and their daily life.

Activity 1.4

This activity proposes the revision of the concept of symmetry from mathematics. Last year, students studied the topic of a quadratic function in this subject. So, we think about taking advantage of this knowledge to get into the concept of symmetry that we need in chemistry. For it, students are encouraged to analyze and review a quadratic function. The task they must do is the following.

In this activity, we will review the different elements that make up the graph of a quadratic function. From the equation 1, you must do the next activities.

$$y= x^2+4x+5 \qquad \text{Eq. (1)}$$

a) Graphing the quadratic function.

b) Recognize axis of symmetry, vertex, and roots.

c) What does the axis of symmetry represent?

d) Where is the vertex of the parabola?

Time allocation for the activity: 80 minutes.

Tasks to be carried out by the students and evidence of achievement of competencies: reading, mathematical calculations, writing answers.

Resources and materials: calculator, online pages.

Evidence of learning: evaluation of the developed exercise.

Indicators that will be considered for the evaluation: presentation of work, exercise resolution, clarity and depth in answers, prolixity and ways of articulating knowledge.

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Phase 2: Presentation and search for new information and new concepts

Activity 2.1

In this activity, students are asked to investigate the corresponding topic according to the detailed text, in groups of no more than two members, and then answer the questions asked. The teacher will submit the following links as complementary material.

- https://www.ecured.cu/Enanti%C3%B3meros
- https://es.khanacademy.org/science/organic-chemistry/stereochemistry-topic/chirality-r-s-system/v/introduction-to-chirality?modal=1
- https://www.dciencia.es/el-enantiomero-bueno-el-feo-y-el-malo/

"Thalidomide is a drug that was used during the first months of pregnancy, between 1957 and 1963 (Gillies, 2017). At the time, it was prescribed for the treatment of several conditions such as irritability, poor concentration, anxiety, insomnia, nausea, morning sickness, hyperthyroidism, and even infectious diseases.

In 1959, an increasing number of newborns began to be reported with a phenotype called phocomelia (limb reduction defects of long bones, in which hands and feet varied between normal and rudimentary), frequently associated with malformations of inner organs. In 1961, Lenz suggested a possible link between the sudden emergence of these congenital abnormalities and the use of thalidomide during pregnancy. Due to the large number of babies born with congenital deformities, this drug was investigated, concluding that it was a racemic mixture of S-thalidomide and R-thalidomide. The S enantiomer was the one that caused the teratogenic effect while the R enantiomer had the desired sedative effect (Gillies, 2017) (Vianna, Kowalski, Fraga, Sanseverino, & Schuler-Faccini, 2017)". Figure 2 shows the pairs of enantiomers.

Figure 2: Chemical structures corresponding to a) S-thalidomide and b) R-thalidomide.

The questions for the students' work are:

a) What is an enantiomer?

b) What does the concept of chirality refer to?

c) Do two enantiomers have the same effects?

d) What do the acronyms R and S mean when used to describe an enantiomer?

Time allocation for the activity: 120 minutes.

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Tasks performed by students and evidence of achievement of competencies: reading, speaking, writing answers.

Resources and materials: text, dictionary, books, online pages, YouTube videos.

Evidence of learning: delivery of written responses.

The indicators that will be considered for the evaluation are a presentation of work, interpretation of the text, clarity in the answers, prolixity, use of the language of chemistry, participation in the class with significant contributions and the analysis of the information presented. In the case of videos, the use of specific vocabulary is required.

Activity 2.2

To begin this activity, the teacher reviews the chemical structures and atomic models studied in a previous unit. And subsequently explains the procedure for determinate if a chemical structure corresponds to R or S enantiomer. As way of example, Figure 3 shows one of the structures worked.

Figure 3. Example of enantiomers (a) (R)-1-bromo-1-chloroethane, (b) (S)-1-bromo-1-chloroethane.

The developed contents will be applied to determine the corresponding enantiomer using simple chemical structures.

Time allocation for the activity: 120 minutes.

Tasks performed by students and evidence of achievement of competencies: exercise resolution.

Resources and materials: class notes.

Evidence of learning: delivery of written responses.

Indicators that will be considered for the evaluation: presentation of work, thoroughness, use of the language of chemistry, participation in the class with significant contributions and use of specific vocabulary.

Phase 3: Application of contents

In this activity and based on the experiences carried out in the previous one, the teachers ask the students to build a molecular model of some simple structure already studied. For this, different materials can be used.

To organize the information, a text that includes different aspects related to the chosen structure is requested, for example, nomenclature, scale, unit of conversion, and choice of materials. Next, students must answer the following considerations:

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- Indicate if the selected molecule is chiral or achiral. If the molecule is achiral, make the necessary modifications so that it becomes chiral.

- Represent the enantiomer of the chiral molecule.

Time allocation for the activity: 120 minutes.

Tasks performed by students and evidence of achievement of competences: exercise resolution.

Resources and materials: class notes, previously developed activities, books, on-line pages.

Evidence of learning: designed and assembled molecular models, elaboration of the report.

Indicators that will be considered for the evaluation: presentation of work, thoroughness, use of the language of chemistry, participation in the class with significant contributions, use of specific vocabulary, creativity in reporting, skill in designed and assembling molecular models.

Phase 4: Socialization of the work done

In this phase, the students will have presented the work done in phase 3. This stage is important because it enables a meeting space where students can develop their potential and ability to learn. Each student will have the opportunity to share their representation regarding an enantiomer. In presentations were included difficulties encountered and questions that may be asked. The teacher will ask them about: What advantages or disadvantages do they find when doing the work? What questions have been prioritized for the presentation? These questions are meant for them to reflect on their own learning process.

Time allocation for the activity: 160 minutes.

Tasks performed by students and evidence of achievement of competences: orality, writing, resolution of problematic situations.

Resources and materials: molecular models, computer, multimedia projector for student use.

Evidence of learning: molecular model, preparation of the report.

Indicators that will be considered for the evaluation: presentation of work, prolixity, use of specific vocabulary, creativity in reporting and presentation and creativity in the design and assembly of molecular models.

Results and Discussion

During the development of activity 1.1 (phase 1), the students thought and expressed the meaning of the concept of symmetry for them. They mentioned samples: balls, butterflies, planes, and Egyptian pyramids. Some students gave examples of the reality they live in school, such us, honeycomb, sunflower, and peacock. Some responses can be seen in figure 4.

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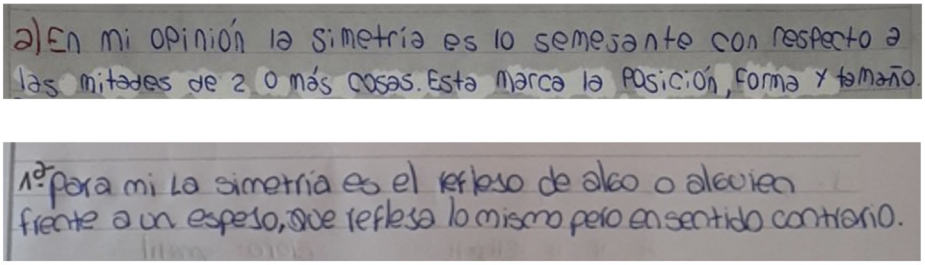

Figure 4. Definition of the term "symmetry" according to students.

In activity 1.2, the students had some difficulty in identifying asymmetrical objects. In addition to those shown in figure 5, they mentioned a cup, a tree, a cow, among others. Concerning the name of enzymes studied in Biology, they had to search in books from the school library and on the internet.

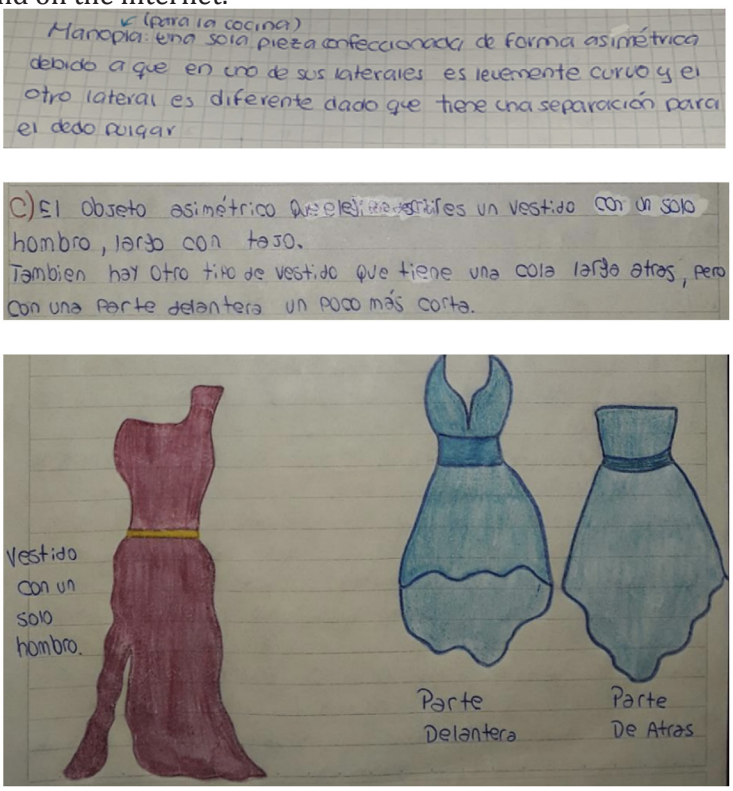

Figure 5. Asymmetrical objects described by students.

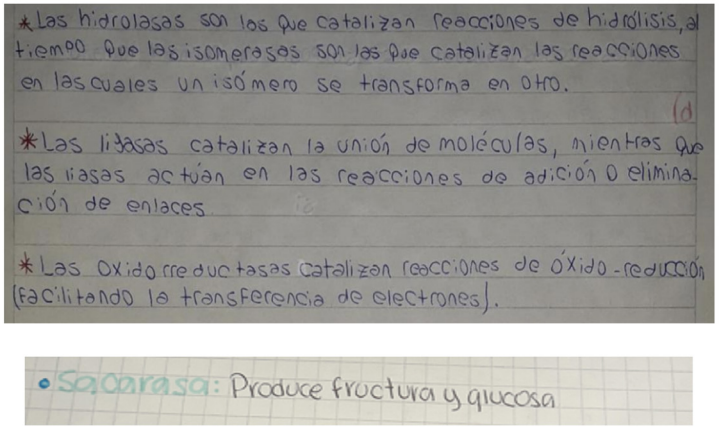

Figure 6. Some enzymes recognized by students.

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The students developed the activity 1.3 according to their own interests, and the results were very interesting, as shown in figure 7.

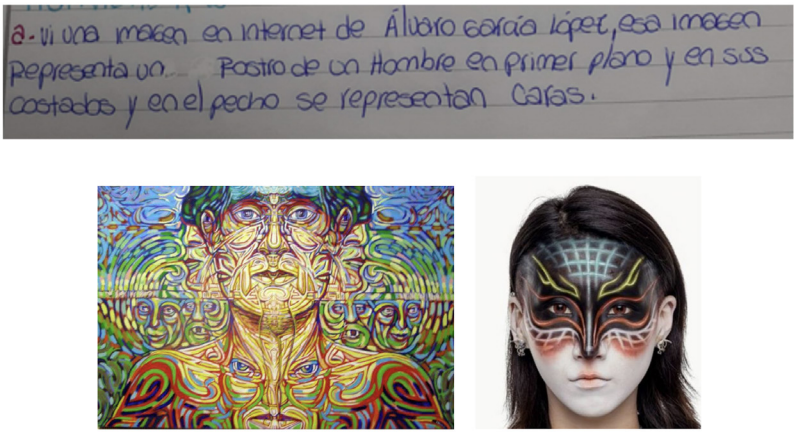

Figure 7. Symmetry applied to art and makeup.

In activity 1.4 the students were able to observe and integrate the concept of symmetry from the point of view of mathematics (figure 8).

Some students presented errors in the calculation of the roots; however, they were able to guess where they should be located on the graph. They correctly identified the vertex and axis of symmetry.

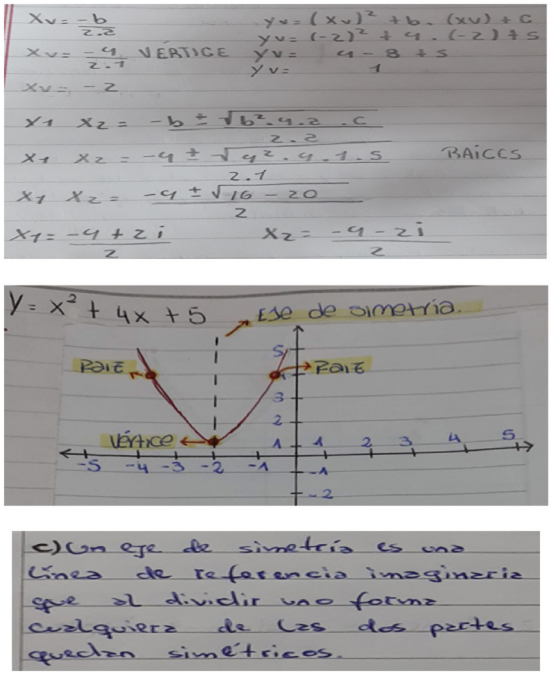

Figure 8. Symmetry applied to mathematics.

In phase 1, the concept of symmetry is discussed from different perspectives. In this way, it is possible to recover previously studied topics. In this phase, the students participated by exchanging opinions. Interesting discussions were generated based on the information they were looking for and what they remembered from having studied in previous years.

In the second phase of the didactic sequence, we began with the study of the concept of enantiomers through a reading of cases that occurred in real life.

Results of activity 2.1 are shown in figure 9.

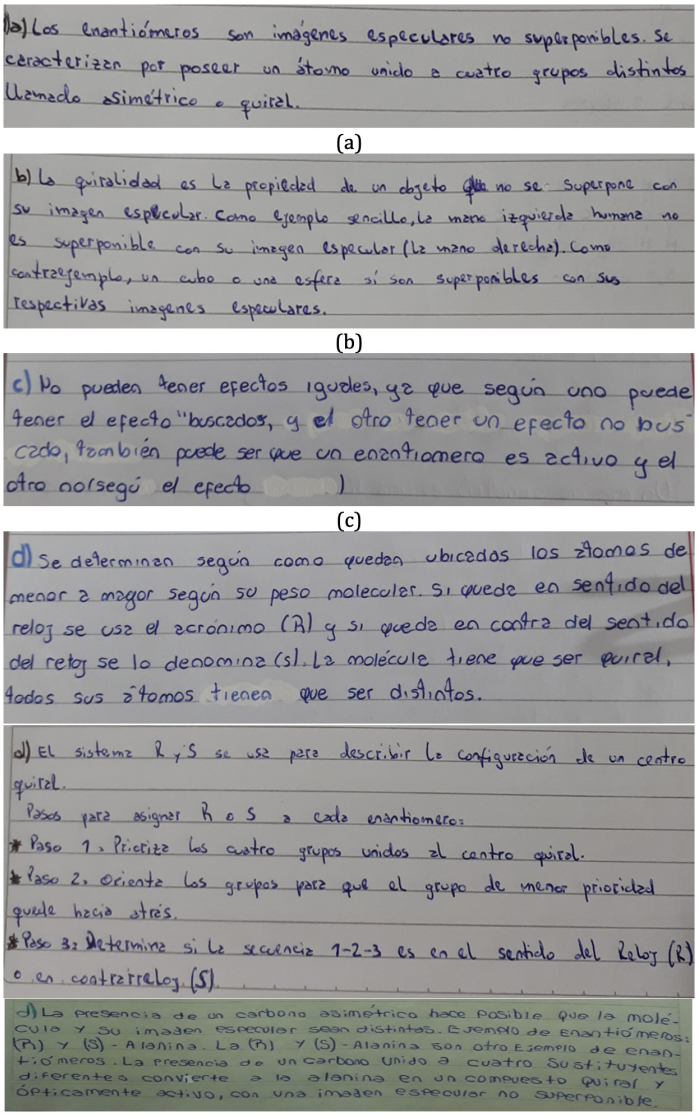

Figure 9. Student's responses to activities 2.1 of sections a), b), c) and d).

When the students read about the problem caused by the consumption of thalidomide, they began to measure the importance of chemistry over time.

In phase 2, the text related to the substance thalidomide allows us to think about what is not known, and thus assess the knowledge and progress of science. This topic is of interest to the students. The questions asked were consistent with academic level.

In activity 2.2 of phase 2, students identified chiral and achiral carbon atoms. To the chiral carbons, they applied the rules to determine if the chemical structure corresponded to an R or S enantiomer. The solved exercises are shown in Figure 10.

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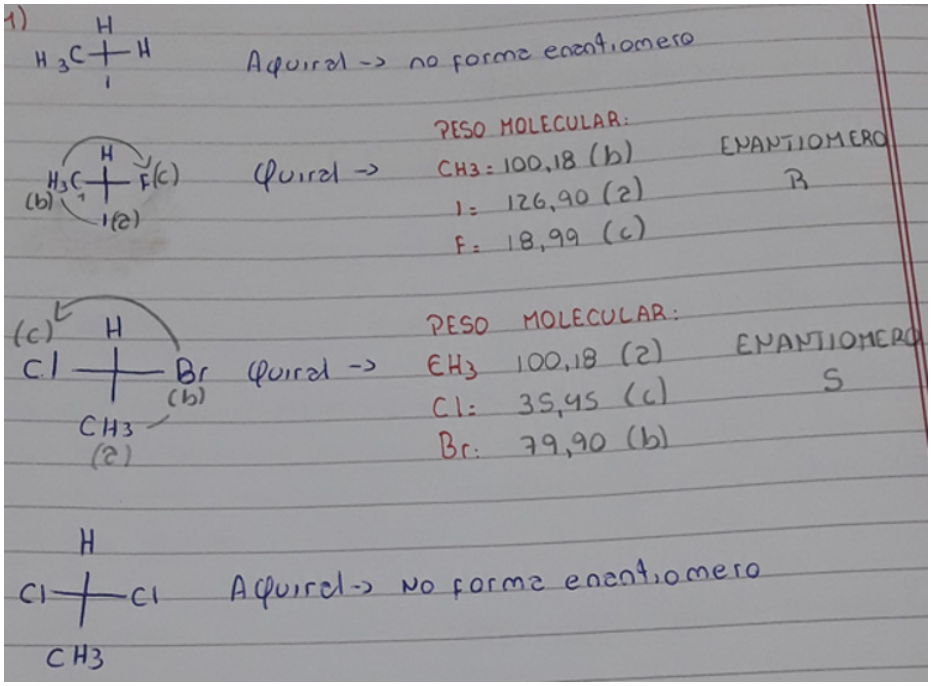

Figure 10. Exercises of determination of enantiomers.

In phase 3, the contents developed in the previous phases are applied. The experience should be enriching and allows partial conclusions to be drawn on how the process work. Figure 11 shows some of the works done.

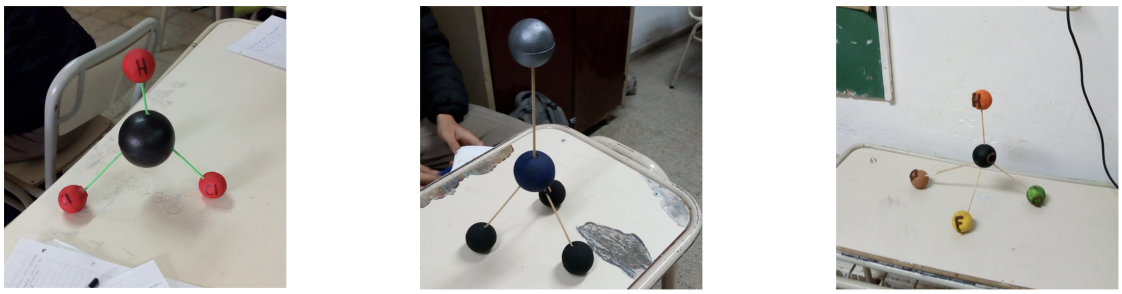

Figure 11. Students in action, designing their molecular models.

Phase 4 allows concluding the topic of enantiomers. During its development, the students had to explain their results.

The indicators considered for the evaluation process were provided to the students before the start of the activities. This is considered appropriate due to the advantages of knowing the evaluation criteria from the beginning.

All reports submitted were evaluated and recorded. The returns are made to the next class. This process must be individual and written.

Conclusions

The activities included in this sequence were intended as opportunities for students to interact at different times and with different objectives.

Each activity makes sense and is connected to each other. Through the articulation of chemistry with art, biology and mathematics, a more comprehensive educational experience is achieved.

The requested task was challenging, and the students have the possibility to face the conflict between what they knew and what to do. In addition, they must mobilize various knowledge, some already acquired and others to incorporate.

Students have developed attitudes for reading, writing and speaking. They were able to recognize, understand and associate enantiomers with aspects of daily lives.

This project was a real challenge and from the results obtained, we believe that this DS can be applied to the study of chemistry in the first years of engineering careers.

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