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# Increasing Students' Understanding of Organic Chemistry In Secondary School In Belgium

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## Abstract

*Organic chemistry is an important part of chemistry, which is not significantly taught in secondary schools in Belgium. Teaching of organic chemistry is often limited to the learning of names and rules by heart, and the assessment of students includes almost solely restitution.*

*A first evaluation of more than 600 students showed that the topics which are the best mastered are the nomenclature as well as the pure restitution of the reactions taught in class. The least mastered point is the understanding of the organic reactions. We also found that several concepts of general chemistry, crucial for the understanding of organic chemistry (chemical bonds, polarity, hydrogen bonding), are still far from being fully mastered. Sadly, the students do not grasp the role of organic chemistry in everyday life. We have therefore decided to develop two learning sequences, the aim of which is to push students to think by introducing more understanding into the chapter of organic chemistry.*

*The first sequence proposes to students to put organic chemistry into context, to make them realize the important role played by organic chemistry in the daily life and to discover for the first time the different chemical functions that they will approach sequentially later.*

*The second sequence is centered on organic synthesis. This enables to summarize all the organic reactions being taught.*


## 1. Introduction

Organic chemistry has a particular place in education, both in secondary school and in higher education. Whether on the side of teachers or learners, organic chemistry is a "difficult" matter to be transmitted, on one hand, and to understand, on the other hand. [1]

Numerous research studies have been undertaken to bring new approaches of teaching organic chemistry during the first or second cycle of higher studies [2-4]. To the best of our knowledge, there is no similar study at the secondary level in Belgium. Thus we proposed in this work to explore the understanding of organic chemistry and to develop learning sequences for belgian secondary schools.

A rapid state of the art showed that the place given to organic chemistry in general secondary education significantly varies from country to country: non-existent in Quebec [5], it holds an important place in the chemistry course during the last three years of studies in France [6]. Belgian educational system is halfway between these two extremes: an introduction to organic chemistry is provided at the third level of secondary education, whichever option chosen [7].

## 2. Methodology

First, a quantitative survey on more than 600 students was conducted. A series of questionnaires covering the entire francophone belgian organic chemistry program was designed in order to increase our understanding and knowledge about how organic chemistry is currently taught in the secondary school system and evaluate the proficiency of students in organic chemistry at the end of the secondary school program.

Various qualitative interviews were also conducted with students. The detailed description of this part of our research will be published elsewhere. The analyses of all these data pointed out two main themes as problematic: (i) the link between organic chemistry and everyday life, and (ii) reactivity in organic chemistry. Based on the students' responses to questionnaires and interviews, two learning sequences were designed and prepared to tackle these identified problems. The first sequence, which will be discussed later in this paper, proposes an alternative approach for introducing organic chemistry, aiming at emphasizing the relationship between organic chemistry and everyday life, and making the students realize that organic chemistry is not limited to the *chemistry of all the living things*, a misconception put forward by many students. Topological writing, not usually taught in secondary


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school, was also introduced as it was well understood in the questionnaires and is by far more relevant for organic chemists. This learning sequence requires three to four hours with the students in the classroom.

The second learning sequence, designed to close the chapter on organic chemistry, proposes to summarize the different chemical reactions taught in class in such a way that students will better manipulate the different reactions and realize that organic chemistry is really the basis for the synthesis of organic molecules worldwide. This sequence, which will be detailed in a future article, will not be developed hereafter.

## 3. Learning sequence – how to introduce organic chemistry at the secondary school?

Our investigations clearly identified that the students lack an overview of what organic chemistry really is. Students do not realize that daily live is much involved with organic chemistry. This shortcoming can be addressed by changing the way organic chemistry is introduced at the secondary school. The goals of this learning sequence are as follows:

- Introduce organic chemistry by contextualization with everyday life
- Avoid reducing organic chemistry as *chemistry of living things*
- Discover the representation of molecules (developed, semi-developed, topological)
- Discover all organic functions taught in the secondary school program for the first time

In this learning sequence, students are asked to list five products of everyday life that are “chemistry” for them. From their answers, the teacher establishes a list of products for which he can determine their main component/molecule, or the molecule that is likely to give the product its distinctive characteristics. For example, gasoline is mainly composed of octane, although it is not the only molecule found in gasoline. If a student proposes *chocolate*, the teacher will retain the theobromine molecule; if a student mentions *clothing*, the teacher may summarize it to nylon; if *drugs* are mentioned, the teacher will choose one, for example aspirin, and therefore the associated molecule, acetylsalicylic acid. The teacher then represents all the molecules he has selected in topological writing and gathers them on a sheet (Fig 1).

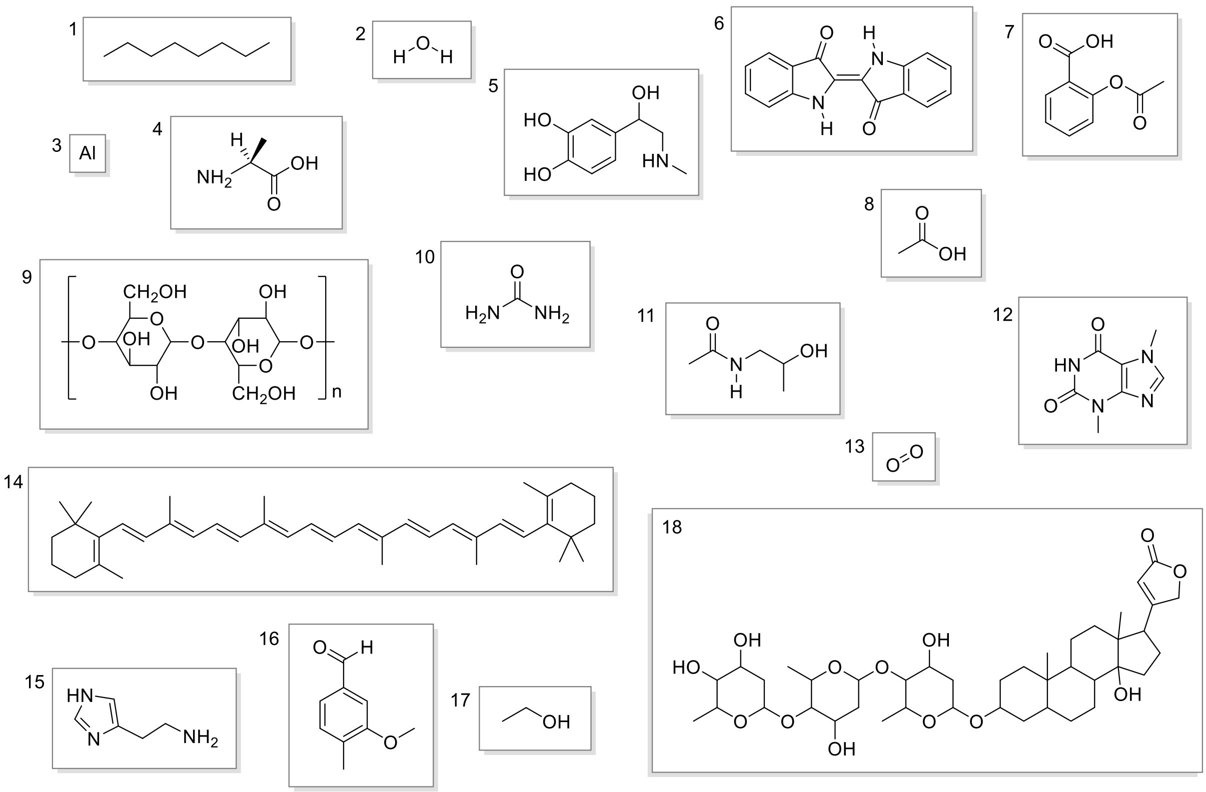


Fig. 1: Example of molecules that can be used to start the learning sequence : 1 : octane (gazoline), 2 : water, 3 : aluminium (metal), 4 : amino acid, 5 : adrenalin (hormone), 6 : indigotin (dye), 7 : acetylsalicylic acid (aspirin), 8 : acetic acid (vinegar), 9 : cellulose (paper), 10 : urea, 11 : N-(2-hydroxypropyl)acetamide (shampoo), 12 : theobromin (chocolate), 13 : dioxygen (air), 14 : beta carotene (vitamin), 15 : histamin (neurotransmitter), 16 : vanillin (aroma), 17 : ethanol (alcohol), 18 : digitalis (poison)

The teacher distributes this sheet to students and asks them if they recognize the molecules. Students can identify the inorganic molecules present (in our example, water, aluminum and dioxygen) but they cannot identify other molecules because they do not know this type of representation. In order to make them able to "*read*" these molecules, the teacher takes some time to explain the different representations generally used in organic chemistry (developed, semi-developed and topological writing), using three small molecules present on the sheet (in our example, octane, ethanol and acetic acid). Starting with the developed structure, the teacher leads the students to understand the different rules of writing for these three types of representation. In order for these representations to be well understood by students, the teacher proposes a first list of exercises to do in the classroom and a second list of optional exercises to do at home for students who need them. We actually observed that after correcting the exercises, some students already express a preference for topological writing.
The main rule of topological writing, namely that carbons are no longer written, naturally brings to the definition of organic chemistry, which is *carbon chemistry*. The teacher can then point out to students that the majority of the products they have cited are part of organic chemistry, avoiding then the misconception that organic chemistry is solely the chemistry of living things.
A first obstacle for the identification of the molecules is also lifted: the students know how to "*read*" the molecules. It still remains a second obstacle: the students do not know how to name these molecules. In a first stage, we do not deal strictly with the nomenclature of molecules, but we more simply identify the different functions they are made of. The identification of functions is the basis of the organic nomenclature, so it is crucial that students are first able to correctly recognize each organic function. The teacher then leads the students to identify all the functions present in the proposed molecules and summarize the results in a table (Fig 2).

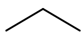
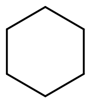
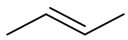
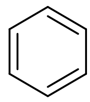
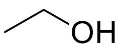
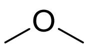
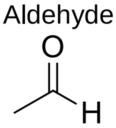
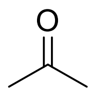
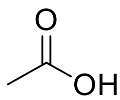
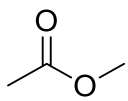
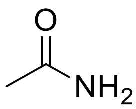
| | **Simple bond** | | **Double bond** | | | |
|---|---|---|---|---|---|---|
| **CH** | Alkane  | Cycloalkane  | Alkene  | Aromatic  | | |
| **CHO** | Alcohol  | Ether  | Aldehyde  | Ketone  | Carboxylic Acid  | Ester  |
| **CHON** | Amine  | | Amide  | | | |

Fig 2: Example of a table containing the organic functions present in the molecules proposed by the students

In order to familiarize students with the different functions, the teacher then asks questions to the class:

- *In which molecule does one find such function?*
- *What functions are present in this molecule?*

The students will then be able to identify the different molecules used in the introduction thanks to a list giving the name of the daily product associated with each molecule, as well as the different functions present in the considered molecule. For example, “Aspirin contains an aromatic ring, an ester and a carboxylic acid”. The list of molecules chosen at the beginning of the sequence must therefore be carefully thought out and constructed in the context of a comprehensive strategy taking into account the different functions that will be addressed.

To conclude the learning sequence, the teacher revisits the presence of organic chemistry in everyday life, asking students if what they see around them is organic or not. In a very simplified way, a majority of products can be identified as organic knowing their origin: if a product is made from something that has been alive, then the product can be considered as organic. For example, paper comes from the trees, so paper is organic; Wool comes from an animal, so it is organic; Plastic is made from petroleum, so plastic is organic. This allows students to determine by themselves whether or not the products that surround them are part of organic chemistry. Of course, this simple approach gives a very rough indication of the organic/inorganic character of a product and suffers from numerous exceptions.

The final evaluation is not based on restitution. A table with the different organic functions is given to the students during the test. They are asked to identify all the functions in large organic molecules, to represent organic molecules in different ways and to determine if some products from everyday life are organic or not. This allows to evaluate the capacities of identification of functions as well as thinking about the place of organic chemistry in everyday life instead of evaluating the learning of functions by heart and their restitution.

## 4. Conclusion

The evaluation of this learning sequence in different schools is currently underway. The first feedback from teachers and students of five classes is very positive. We hope that this approach to organic chemistry will enable students to develop a more practical understanding of the importance of organic chemistry by providing tools to recognize organic products and molecules, such as topological writing, and a way to easily determine whether or not a product of everyday life is part of organic chemistry.

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