DEVELOPMENT OF ONTOLOGICAL KNOWLEDGE REPRESENTATION: LEARNING HYDROCARBONS WITH DOUBLE BONDS AT THE SECONDARY LEVEL

Tamara N. Hrin, Mirjana D. Segedinac, Dušica D. Milenković
Department of Chemistry, Biochemistry and Environmental Protection,
Faculty of Sciences, University of Novi Sad, Serbia
Corresponding author e-mail: tamara.hrin@neobee.net

ABSTRACT

This paper presents the development of an ontological knowledge organization and representation, and explains how application of appropriate methods for its visualization can lead to meaningful learning. We have applied systemic diagrams (SD) as a method of visualizing ontological knowledge organization. Seven ontological models for *"Hydrocarbons with double bonds"*, following the development from concept map to systemic diagram, are constructed. Chemical properties of alkenes are particularly elaborated and represented as a final systemic diagram (SD_f). *[AJCE, 3(2), June 2013]*

INTRODUCTION

Ontological Knowledge Organization and Representation

Learning and knowledge are closely related concepts. The way in which the student learns determines the type of resulting knowledge (1) or results in the corresponding quality of the acquired knowledge. During learning, i.e. acquisition of knowledge, students are faced with the problem of understanding of a new domain, as there are many new relationships among concepts, facts, or rules that seem arbitrary and confusing (2). The question is, what is a good method of teaching and learning by which one can overcome the problems of lack of understanding of the new domain, and how to facilitate learning of concepts which are often numerous and abstract to the students? In order to answer these questions, we will look at the process of acquiring knowledge.

Knowledge acquisition process requires three stages: knowledge elicitation, knowledge analysis, and knowledge representation (3). Successful analysis and knowledge representation require an efficient way of organizing knowledge which will allow development of knowledge base (Figure 1). How a knowledge organization enables the creation of rich knowledge base, and what is the connection among knowledge elicitation, analysis, representation and organization, can be explained by Piaget's model of equilibration and cognitive schemes (4).

Piaget's model of equilibration describes a process in which people accept new information from the environment (knowledge elicitation), how they perceive and experience them (knowledge analysis), and finally, how they integrate these new information into their own knowledge base, through cognitive schemas (knowledge organization). Piaget pointed out the existence of cognitive schemes that are developed and formed through the coordination and internalization during the activity with given objects (5). An object can be integrated into the scheme, during the action, which has been carried out on it (4). These schemes are the result of a process of adaptation to the complex experience (actions), such as interpretation and integration of objects we are facing. In schema-based knowledge objects are linked together and organized into sophistical hierarchical structures (6). As cognitive units, schemas represent a higher level of organization than a simple collection of lower-level components (6). Sweller (7) has emphasized that knowledge and intellectual skills based on knowledge are highly dependent on the scheme acquisition.

Brinkman (8) has emphasized that in order to be useful, knowledge must be organized in the way to facilitate understanding and to develop problem-solving skills. Novak (9) has pointed out that the quality of learning depends on the conceptual richness of new material that needs to be learned, as well as on the quality and quantity of relevant knowledge organizations. So, organization of knowledge must be clear and understandable, to enable correct learning of new facts, to provide connections, as well as drawing conclusions based on the adopted facts, linking new and previously acquired facts. The final goal of learning process is integration of new knowledge into the system of previously acquired knowledge, and it is the main characteristic of meaningful learning, which is described by Ausubel (10) and Novak (11).

In the opinion of Fahmy and Lagowski (12), Ausubel's important contribution is distinction that he has observed between mechanical (rote) and meaningful learning. By Ausubel (10), meaningful learning is manifested in students if they unarbitrarily and essentially connect new concepts with those already adopted. And rote learning occurs when material which has been taught does not have an established relationship with the previously learned. Figure 1 shows the relationship between good knowledge organization and meaningful learning, which are linked by the fact that they enable the scheme acquisition, leading to the integration of new knowledge into the system (base) of knowledge.

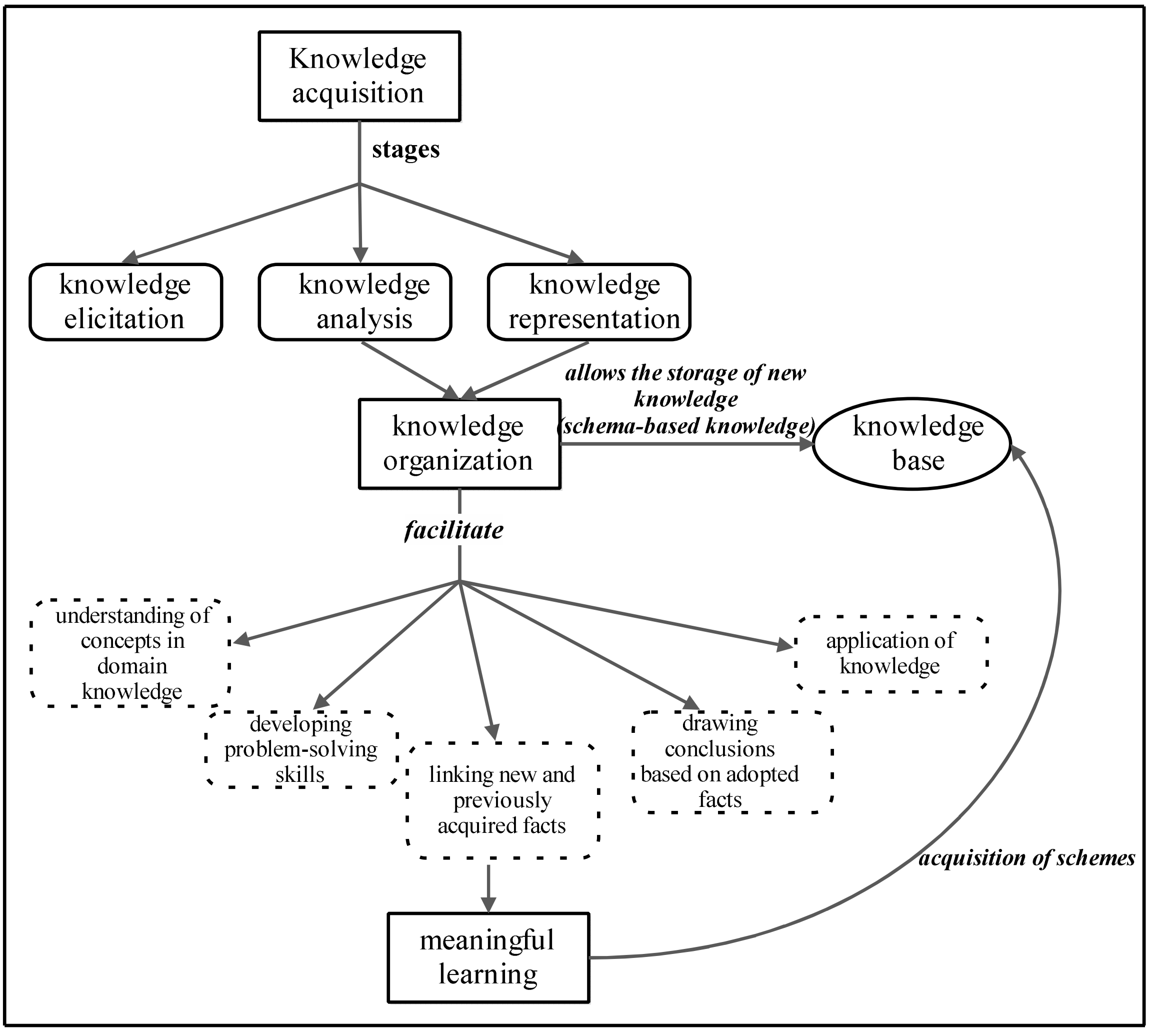

Figure 1: Relationship between good knowledge organization and meaningful learning

The question is how to provide the organization and representation of knowledge that can contribute to meaningful learning? To achieve good organization (representation) of knowledge, an appropriate method of teaching and learning can be applied. A good method of teaching must create rich and stable knowledge base system, and in chemistry this system comprises: chemical scientific theories, chemical laws, chemical scientific concepts and facts (13).

Kim and coauthors (14) have pointed out that knowledge organization has a fundamental role in the successful knowledge representation, and thus allowing application of knowledge. This group of authors describes use of ontologies for knowledge organization in a given domain. In the context of computer science, ontologies have been applied in the field of artificial intelligence in order to facilitate knowledge sharing and reuse of acquired knowledge (15). Soon, ontologies have gained great popularity. They have been expanded to the fields of knowledge engineering, natural-language processing and *knowledge representation*. The reasons for the rapid extension of application of ontologies are providing understanding in domain knowledge and clear communication between users (students) and application system (ontological model).

In the context of knowledge representation, ontology is defined as a formalization of the concepts of application domain (16), or as a specification of conceptualization (17). Ontology presents concepts of domain of interest, and relationship that are relevant to the particular application domain, creating a vocabulary of that domain. In the ontological knowledge organization, given concepts are grouped into classes, and classes are often arranged in the form of hierarchical set. To visualize the ontological knowledge organization, to design and construct ontologies, a variety of graphical tools – ontological models (ontological diagrams), might be applied. Kim and coauthors (14) use knowledge maps, noting that for the same purpose concept maps, semantic networks, Petri nets and structures named frame can be used. Zipp et al. (18) have stated strategy which involves usage of mnemonics, traditional hierarchical note taking, charts, scientograms, mind maps, and concept maps.

In the course of learning complex, unknown contents, we are passing through the appropriate stages of learning. The first phase occurs with storage of isolated concepts, and therefore we do not have schemes for interpretation and integration of pieces of information we are facing (19). At this stage, during the memorization of the more or less isolated concepts, mnemonics can be useful. As learning progresses, these concepts are grouped and organized, and then integrated into higher order structures. At this stage, mnemonics does not play an essential role. Instead of mnemonics, several other types of knowledge organization can be more useful, for example hierarchies and matrixes (19). Then the nature of learning is changing, starting from a completely linear manner to more associated manner of knowledge representation.

But, all of these techniques, which tend to foster and promote meaningful learning, more or less develop concepts in a linear manner. In hierarchical note taking, concepts are listed in categories, e.g. from superior to inferior, using the spatial model from left to right. With the mind map, students use visuospatial, rounded relationships, moving with branching from central theme (central concepts) to peripheral concepts (18). Chen (20) has been using ontologically modeled concept maps – graphical structures in which concepts have been shown in the vertices of the diagram, and relationships between them have been emphasized placing arrows (21) in the appropriate directions.

In constructing concept maps, we start from the top, where most general concepts are placed, moving to the lower parts where more specific concepts are placed, linking them with arrows. Based on his research, Chen (20) has concluded that concept maps could be applied for adoption and mastering difficult material for learning, establishing connections between new and previously acquired concepts. However, it should be noted that in concept maps relationships among concepts are linear, and therefore all existing relations between them can't be seen. Fahmy and Lagowski (22) point out that it is difficult to achieve a global view of the collection of linearly arranged concepts. To overcome this lack of concept maps, they introduce systemic arrangements of concepts, where all relations between them are set out explicitly (22).

Interest of Fahmy and Lagowski for concept maps is reflected in structural similarities with systemics, but we want to emphasize that these two strategies have a common root – the ontological aspects of presenting the concepts in the domain knowledge. The difference is that systemics are able to provide more global view of the concepts and their relations, because they can be taught of as a "closed concept map cluster" (23), and thus allow better assimilation of knowledge, by storing knowledge in long-term memory. Observing the relations shown in Figure 2, we can conclude that systemics are very favorable method for organizing and representing knowledge because of connection of new information with those already adopted. Thus we can provide a meaningful learning for students who apply this teaching and learning method in the learning process. It can be said that systemics have taken all good features of concept maps, while at the same time improving or eliminating their disadvantages (13).

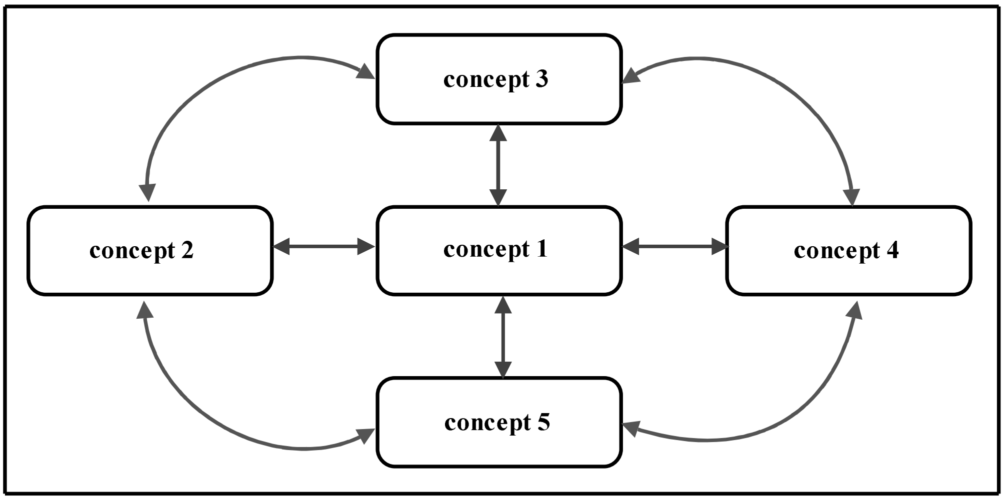

Figure 2: *Systemic diagram (SD) with five concepts*

METODOLOGY

Learning organic chemistry is often confusing to students who find it as a huge maze of structural formulas and reactions, which in their view can be mastered only by mechanical memorization. On the other hand, organic chemists the same field find very well-ordered, with elegant simplicity (24). To achieve such knowledge organization, all concepts in a given domain must be represented in the right way. It means that concepts should be clearly stated, with all necessary features, and properly established relations of these concepts with others in the same domain. Considering this problem, we have chosen Systemic Approach to Teaching and Learning Chemistry [SATLC] (12, 22-24, 26-28) as a method of representing concepts, relying on the Fahmy and Lagowski's statement that systemic diagrams (SD) facilitate the understanding of relationships between concepts in a broader sense (23). SD is the key for creating teaching units, in accordance with the principles of the SATL method (26).

In this paper, SATL method is applied in the part of one chemical teaching topic – "*Hydrocarbons with double bonds*". The scope of chosen concept satisfies high school level. As part of this teaching topic, students learn alkenes and dienes as acyclic hydrocarbons with double bonds, and cycloalkenes and arenes as cyclic ones. Each of these classes of organic compounds is characterized by certain type of chemical reaction. Classification of hydrocarbons with double bonds, as well as types of their characteristic chemical reactions, is linearly shown in Figure 3.

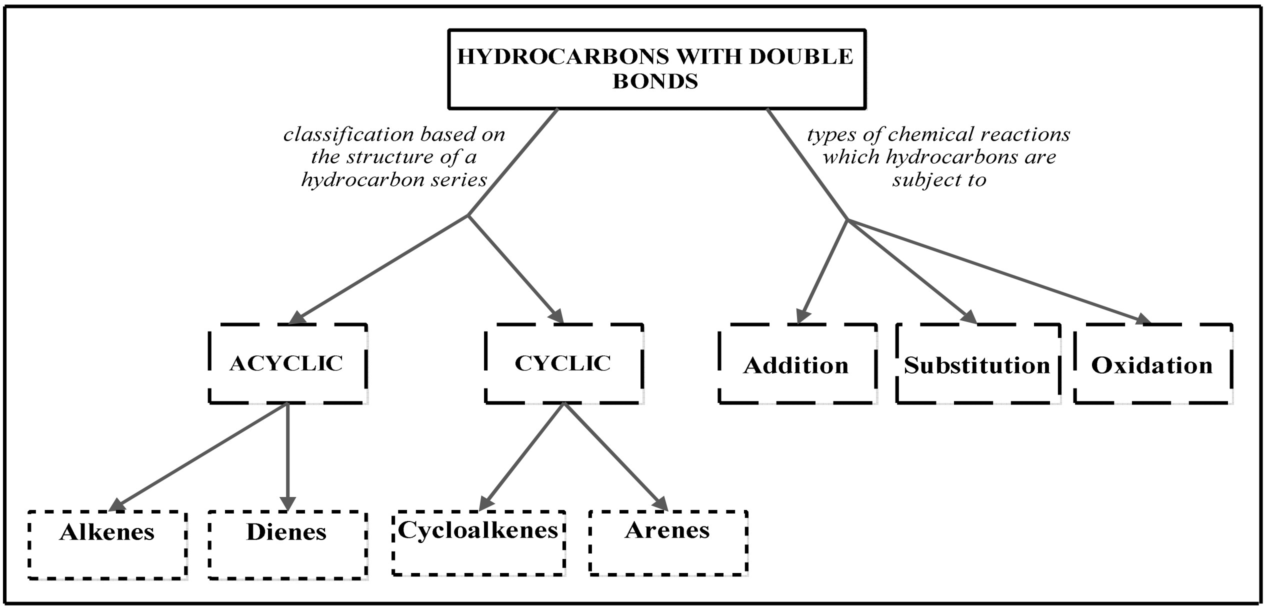

Figure 3: *Concept map for hydrocarbons with double bonds*

For alkenes, characteristic reactions are addition and oxidation. Combining fields in which we indicate alkenes, with the fields in which we indicate addition and oxidation, we obtain two unknown relation: *1? - How alkenes are associated with the reaction of addition*, and *2? - How alkenes are associated with the reaction of oxidation* (Figure 4).

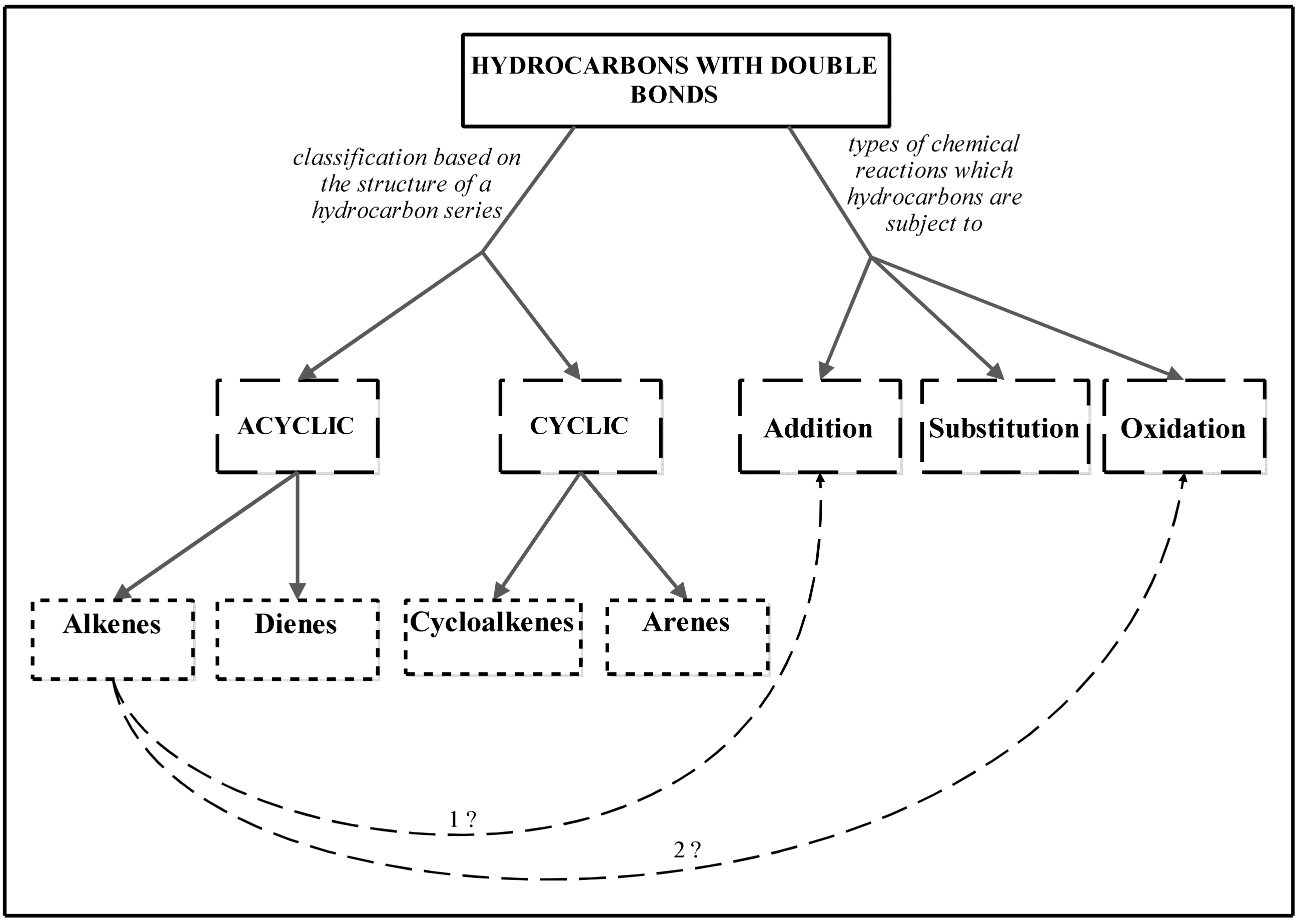

Figure 4: *Concept map for hydrocarbons with double bonds, which is extended by connecting alkenes with reaction of addition and oxidation*

After completion of this teaching topic, students need to know (*the goals of learning*):

a. what type of reaction corresponds to each class
b. which relationships connect one class with other classes of hydrocarbons with double bonds

c. which relationships connect that class with the previously learned classes of organic compounds. Previously learned classes of organic compounds are alkanes, cycloalkanes, and alkyl halides.

To achieve these goals, we first need to display a concept map, which will specify the scope of desirable concepts. Concept map includes concepts such as: selected class of organic compounds (alkenes), types of chemical reactions and products of a given chemical reactions (Figure 5).

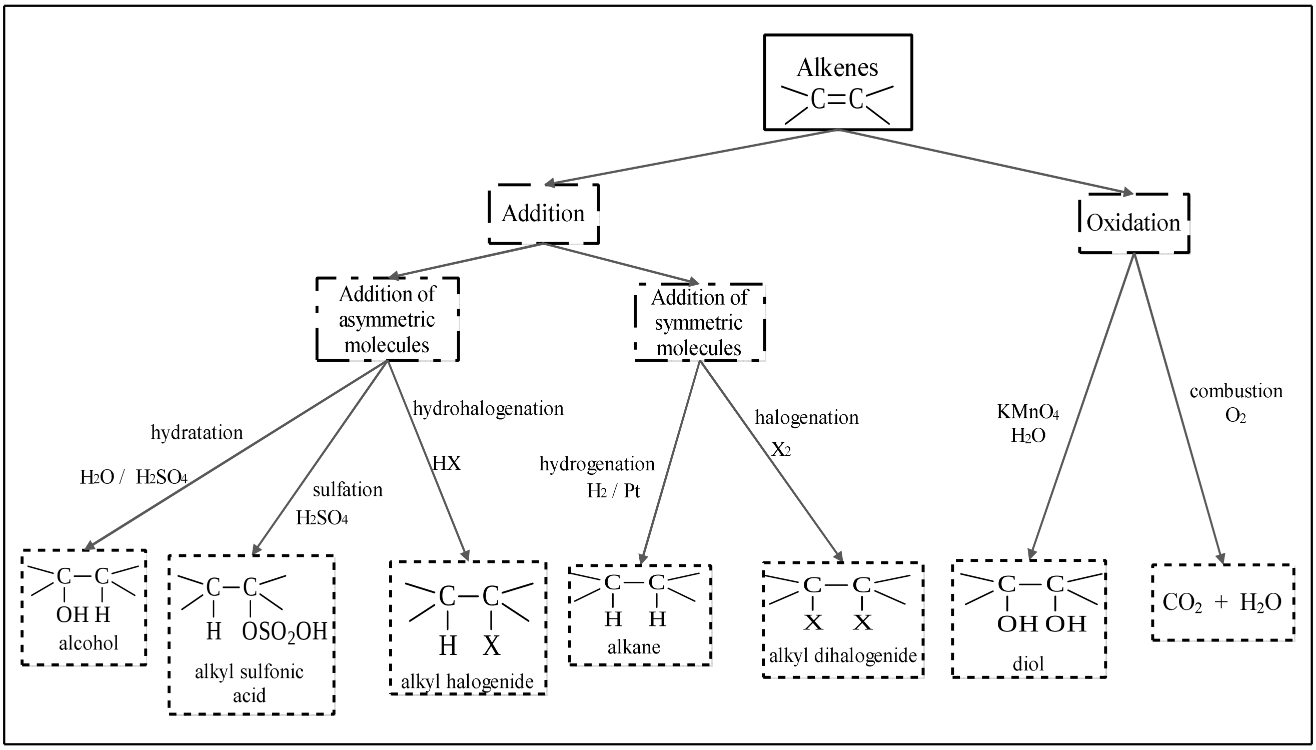

Figure 5: *Concept map which presents chemical properties of alkenes*

Using a concept map from Figure 5, students can learn the chemical properties of alkenes, however, they cannot reveal the deeper connection between the resulting products. So, using a given concept map, students can meet goal a., but cannot meet goal b. or c. In order to accomplish the goal c., it is necessary to set the relationships between the obtained products. In such way we construct the initial systemic diagram (SD_0, Figure 6), which assures an equal starting point for all students (26). After all students have mastered the characteristic chemical reactions of alkenes (using concept map), they are now ready to move to the next step of learning process - connecting all concepts in the domain.

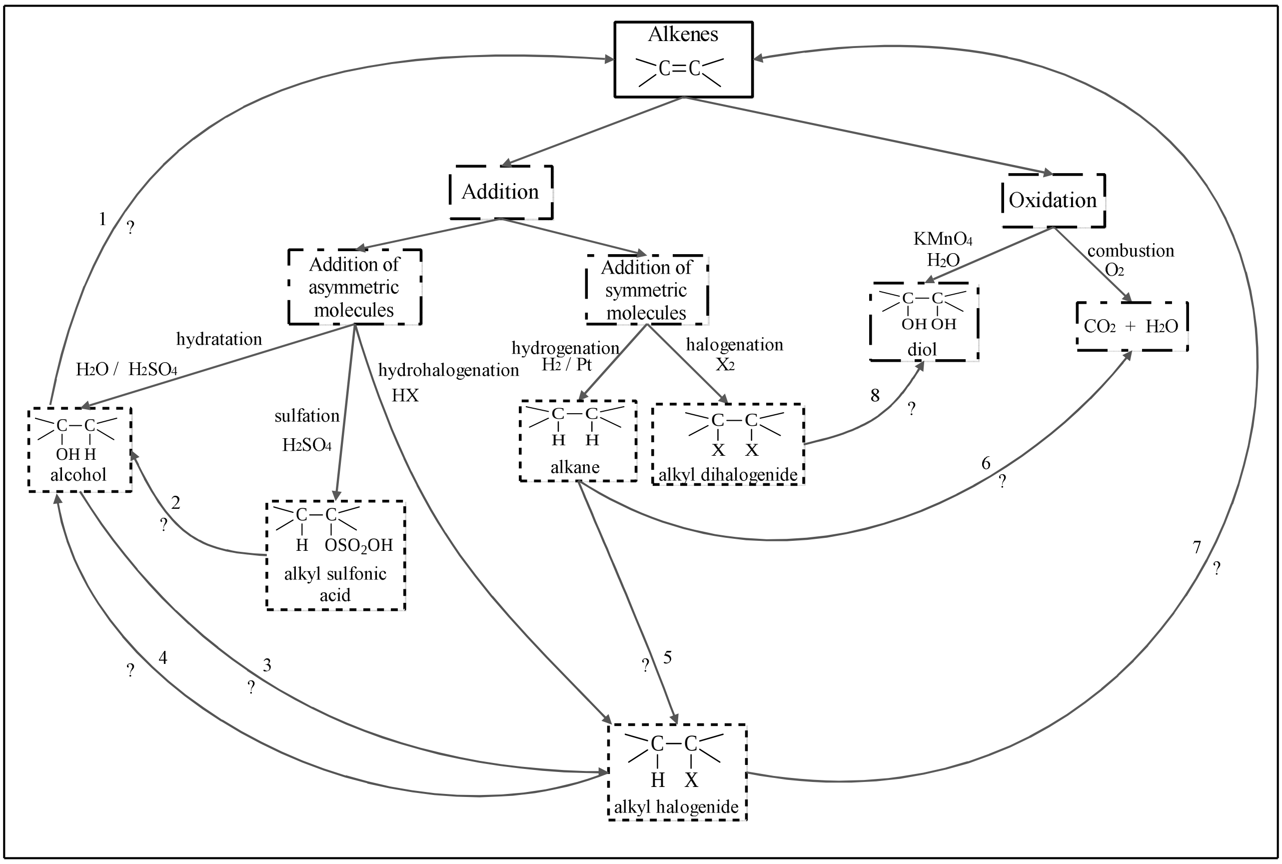

Figure 6: *Initial systemic diagram (SD_0) which presents chemical properties of alkenes and unknown relations between obtained products*

When students, together with their teacher, have discovered all unknown relationships outlined in Figure 6 (from unknown relation 1 to unknown relation 8), we are getting the final systemic diagram, SD_f (26). So teaching unit ends with SD_f (Figure 7), in which all relations among given set of concepts are clearly indicated. Specification of unknown relationships from Figure 6 is shown in Table 1.

Table 1: *Specification of unknown relationships from Figure 6*

Number	*Specification*
1.	cc H_2SO_4 / 180 ^{0}C
2.	H_2O
3.	HX
4.	KOH
5.	X_2 / hυ
6.	Combustion; O_2
7.	cc KOH
8.	1. CH_3COOH; 2. NaOH

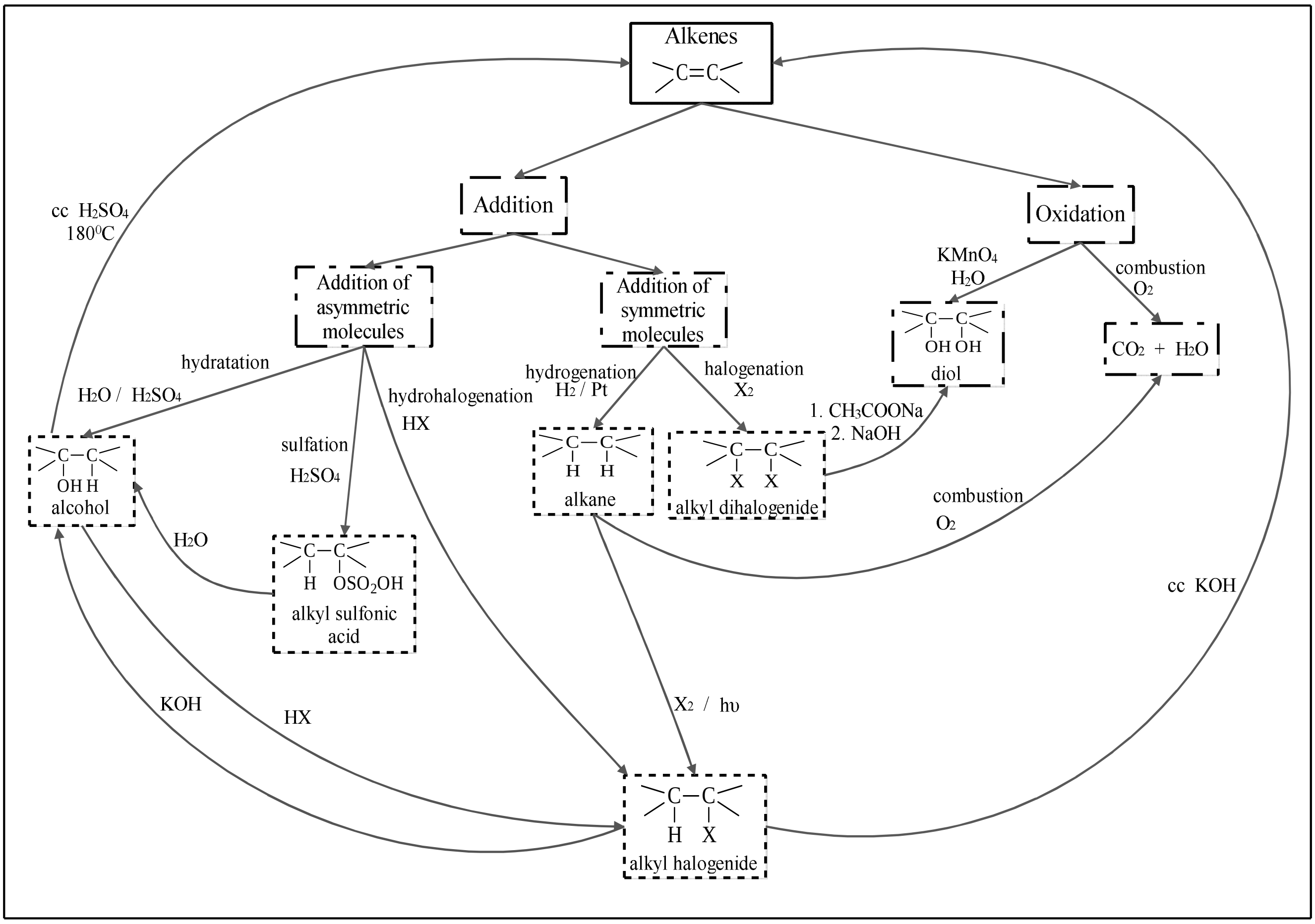

Figure 7: Final *systemic diagram* (SD$_f$) *which presents chemical properties of alkenes and all existing relations among given set of concepts*

DISCUSION AND FURTHER APPLICATIONS

In future work, in order to meet the goal b., we should likewise construct systemic diagrams for dienes, cycloalkenes and arenes. Then, it would be able to contemplate relations among all classes of hydrocarbons with double bonds.

However, the aim of this study was to consider the SD from the perspective of the ontological knowledge representation and organization, and to show the benefits of their application in comparison to other methods of ontological knowledge representation. In order to determine the true methodological value of our systemic diagrams in the teaching process in high school, they should be tested in the form of the experimental teaching, where diagrams are used as an instructional and learning means. However, since there are many papers which confirm the improvement of students' achievement when they use systemic diagrams in learning process (12, 22, 23, 27, 28), we'll look back for some new additional facts. It would be very interesting to determine whether there is a correlation between student achievement and cognitive load, comparing students who learn with systemic diagrams and those who learn without them. Establishing this relationship is going to be one of the main tasks of our further research.

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