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Experiences in Teaching and Learning

Learning organic chemistry day by day: The best choice of the best pharmacy students

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ABSTRACT

Background and purpose: During over ten years of experience in teaching organic chemistry at the Department of Pharmacy we have tried to answer the following question: why do most students tend to take the exam one, two, or more years after the end of the course they have attended? Several reasons could justify this delay, but three seem to be the most common drawbacks for our students: a) time needed for the comprehension of the arguments; b) the number of mandatory exams to pass before organic chemistry; c) lack of a self-evaluation method.
Educational activity and setting: To increase the number of students in the exam sessions of the semester just after the course we have proposed two strategies: 1) a systematic, but stressless, approach by which homework and everyday life examples concerning organic chemistry are used to increase the sense of responsibility in studying; 2) the modification of the number of mandatory exams required for organic chemistry.
Findings: The rate of successful students in the exam sessions at the end of the course increased from 38.3 up to 61.3%. Interestingly, the highest scores tend to be obtained by students in the first session available just after the conclusion of the course.
Discussion and summary: The combined effect of Strategy 1 and Strategy 2 seems to be effective in promoting the learning of organic chemistry and points out that the best performances tend to be associated with students which follow organized studying.

Background and purpose

Organic chemistry is all around us: this is the most common way to introduce the course in textbooks.[1–9] Although some methods have been proposed to improve learning, this discipline still represents one of the most dreaded courses for undergraduate students.[10–13] During our experiences in teaching we have tried to change this perception by increasing the numbers of examples and exercises discussed in class showing how organic chemistry follows logical steps predicted by specific rules. Extensive time in the classroom allowed us to obtain good feedback from our students in order to understand their difficulties in learning. We use class break time to talk about the arguments just explained and to encourage questions students may consider too silly to be asked in front of the class or during office hours.

Our students are introduced to organic chemistry in the first semester of the second year. They are divided into two groups following alphabetic order and are equally distributed into two classrooms with the same syllabus and timetable. Each group is assigned to one teacher for the entire course. Lessons take place three times a week from October to January. Course attendance is compulsory and different sessions for the qualifying exam can be selected by students at the conclusion of the semester: the early

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session (February), the first summer session (April), the second summer session (June–July) and the autumnal session (September). Students can choose which exam to take but not necessarily in the semester at the end of the course they have attended. In the case of failure they can repeat the exam in the next session. The exam is divided into two parts. Each part must be passed in the same session and is mainly based on the knowledge and comprehension of functional groups and their reactivity, systematic and common nomenclature, stereochemistry, and acidity/basicity of the organic molecules. The first part consists of a two-hour test in which students have to write the correct solutions to six problems (drawing molecular structures from the IUPAC names and vice versa; completing reaction mechanisms with particular attention to the stereochemistry of the products; discussing the strength of given compounds as acid or base by comparing pK_a values).

Only students graded with a positive score (from a minimum of 18/30 to a maximum of 30/30) can access the second part: an oral exam in which they have to show their level of mastery by writing on a board in front of all of the other students by using appropriate symbols and formulae to describe transition states, intermediates, tautomerism, and acid-base equilibria. Finally, they are graded with a single score. Laude is added to 30/30 score if high reasoning capability is shown during the examination. Until the 2014–2015 academic year three qualifying exams in mathematics, physics, and general inorganic chemistry were mandatory prior to taking the organic chemistry exam.

During our experiences in teaching we have tried to facilitate the comprehension of this discipline by adopting several methods from known learning theories.

Generally, four theories are employed to describe the mechanism by which the acquisition of information becomes knowledge in the learning process: behaviorism, cognitivism, constructivism, and connectivism. In the first theory, studying is planned and organized by the teacher, while students write notes, memorize concepts and answer the teacher's questions after the principle of stimulus-response.[14,15] In the second theory, learning comes from problem solving: the teacher assists students in memorization and storing information by using existing schemes or concept maps to formulate cognitive associations.[16] In particular, concept map assignments seem to help pharmacy students to reinforce and enhance the topics presented in class. Moreover, the best scores from the graphic response, rather than oral assessment, tend to be obtained from the same student.[17]

Both behaviorism and cognitivism are acquisition theories in which learning is a passive process based on the central role of the teacher. In the pharmacy education context, instructional strategies based on the acquisition of learning by using known facts in everyday life seem to be more efficient in developing student cognitive abilities and skills in application to practice.[18]

A drastic inversion of the roles is observed in constructivism and connectivism.[19,20] Both are participation theories based on the concept of learning as an active process centered on the direct involvement of students, while the teacher becomes a facilitator, able to provide guidelines and encourage students to become thinkers. In constructivism, the teacher supports students in working together to ask and answer questions and promoting discussions. In connectivism, the role of technology in the social context of the digital age is emphasized: learning comes from networks with databases and digital platforms in which students find materials, follow online course and make self-evaluation tests.[21] Recently, it has been pointed out that pharmacy students strongly improve their engagement in learning by using social media, such as Facebook and Twitter.[22,23]

Previous papers have shown how a combination of the mentioned theories should be employed to reach effective results in the light of the large variety of problems and difficulties which could affect students during the learning process.[24–26] Moreover, despite the adopted teaching theory, students decide for themselves how much to be involved in learning.[27]

Our approach has always been based on both the key role of the teacher and the active role of the student. The teacher has to make organic chemistry reasonable explaining logical rules to understand properties and reactivity of the functional groups. The student has to take in the explained concepts and apply them to recognize or predict the behavior of a given organic molecule, but above all she/he must be willing to learn organic chemistry. After explanations of a given argument, we solve exercises previously assigned in the exam sessions and available online on the web page of the department to demonstrate the level of difficulty of the exam. Participation of students, alone or in groups, is promoted by quick questions prior to showing how to write or think clearly to solve the exercise.

Since the beginning of our experiences in teaching, our teaching method has been centered on the classification of the compounds as electrophiles or nucleophiles, acids or bases with the aim to minimize memorization and maximize understanding as described by the following examples:

Example 1. The definition of Brønsted acidity is repeated, as well as the main factors affecting the strength of a generic acid, before introducing a functional group having acid behavior. In this way, the higher acidity of phenols in comparison to aliphatic alcohols becomes reasonable and the pK_a values are the only information students have to memorize.

Example 2. The definitions of nucleophile and electrophile, as well as the main factors affecting their strength, are repeated to identify the chemical behavior of a given class of compounds. In this way, the reactivity of the Grignard reagents as strong nucleophiles or strong bases, becomes reasonable. Consequently, students have to recognize what electrophile or acid is present in a given reaction involving Grignard reagents.

Example 3. The definition of basicity is repeated, as well as the main factors affecting the strength of a generic base, before introducing a functional group having basic behavior. In this way, the higher basicity of cyclohexylamine in comparison to aniline and pyridine becomes a consequence of their structures and the pK_a values of the relative ammonium ions are the only information students have to memorize.