Classroom Innovation: Games to Make Chemistry More Interesting and Fun

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Abstract: Many students of agronomy engineering, who are required to take organic chemistry, find the class unpleasant and uninteresting because they feel forced to learn concepts that they regard as irrelevant to their career plans. When this lack of motivation is combined with limited self-discipline, students don't study and, thus, fail to learn the subject. This paper presents a method of adapting the course materials and methodology to the student's needs by the inclusion of appropriate games. These games help to create a less formal atmosphere and add variety to the class, and they can even be used as methods of evaluation. Students exposed to this method are more apt to experiment and participate freely in class.

Introduction

For several years, we attempted to change our class materials and methods to make them more accessible and to motivate our students. We adopted several teaching/learning strategies: constant communication between teachers and students, thoughtful reading, questionnaires about different topics assigned for investigation, summaries (charts or conceptual maps at the end of each studied chapter), review sessions for those who take longer to learn the material, and, upon request, clear explanations and guidelines for problem-solving.

After covering the subjects in the first chapter, we undertook the task of evaluating what our students had learned in the Organic Chemistry class. For this purpose, we provided them with a quiz including all the concepts that had been developed during the previous class sessions. To our great surprise, we noted that a majority of the students were not able to solve the quiz problems and showed little interest and a limited ability to associate the new material with elements already present in their cognitive structures.

These results encouraged us to break with the more traditional methods and change the way we assess our students' knowledge [1].

We decided to use games, including word maze, dominos, crossword puzzles, other puzzles, and card games. This was met with enthusiasm by our students; their level of interest increased and it confirmed our belief that the emotional approach plays an important role in the teaching-learning process.

Why Games?

There are several valid reasons for using games. Students, in the more informal atmosphere produced by playing games, are less self-conscious and, therefore, more apt to experiment and participate freely in class. In addition, games automatically stimulate student interest; a properly introduced game can be a very good motivating technique. Games can also be used to focus the students' attention on a specific structure; they may function as reinforcement, review or enrichment, and they contribute to an atmosphere of healthy competition as well as ensure a great amount of student participation. Furthermore, teachers usually get immediate feedback by using these kinds of activities. Finally, we must not forget that the inclusion of games provides variety to the class (even when used as evaluating methods) and we feel that *variety* is motivating.

Examples of Games

Dominos. One of the games we developed is a dominos-type game that can be used by two teams of players. The aim of the game is to join the correct pieces, which will create a structure that can be chosen from the following list:

- 2,4,4,8,8-pentamethylnonane
- 1-cyclohexyl-2-methyl-3-hexene
- 3,3-dimethyl-5-phenyl-2-heptanol
- 3-amine-10-undecenoic acid
- (*p*-isopropyl)-1-phenyl-1, 3-butanodione

Each dominos piece represents a fragment of the molecule; it is necessary to arrange them correctly. It is important to notice where the molecule can be fragmented, thus it is possible to infer how many pieces will be necessary to make it.

For example, to make the structure (a), the student must collect five pieces. In one of them, they must identify an isopropyl group in which they can recognize two primary carbons and a tertiary one. Two other pieces represent quaternary carbons, but they are different, one of them contains two methyl and the other contains three methyl groups.

The four methylene groups are separated as follows. Three of them are consecutive and the remainder are alone. All are secondary carbons; however, their sites in the proposed structure are not interchangeable.

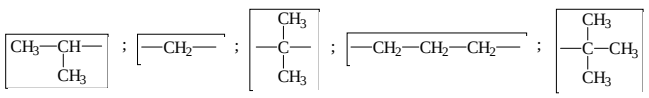

Table 1. Chemical "Cards"

First Set of Cards[a]	Second Set of Cards
1. toluene	1. $Cl_2/AlCl_3$
2. 2,2-dimethyl-propane	2. $Cl_2/h\nu$
3. 3-methyl-2-butene	3. H_2O/H^+
4. benzene	4. Br_2/CCl_4
5. orthochlorobenzene	5. HBr
6. nitrobenzene	6. $CH_3COCl/AlCl_3$
7. 2,2-dimethyl-1-chloropropane	7. $CH_3Cl/AlCl_3$
8. parachlorobenzene	8. CH_3OH/ H^+
9. 2,3-dibromo-3-methyl-butane	9. a) $CH_3CH(MgBr)CH_3$
10. 3-phenyl-propanaldehyde	9. b) H_2O, H^+
11. 2-methyl-2-bromo-butane	10. Zn(Hg)/HCl
12. butanoic acid	11. H_2 , Pt
13. methyl butanoate	
14. metanitroacetylbenzene	
15. 2-methyl-5-phenyl-3-pentanol	
16. 2-methyl-butane	
17. 3-methyl-butanone	

[a] The molecules can be represented by their structures or their names.

Z	P	Y	K	R	I	S	O	M	E	R	I	S	M	L
A	E	E	T	H	Y	L	E	N	E	M	B	O	Y	P
R	B	C	N	T	D	O	R	T	O	F	G	Z	H	E
O	F	M	E	T	H	Y	L	K	L	N	N	O	P	N
M	A	R	T	R	I	P	L	E	Z	E	E	M	H	T
A	A	L	E	M	E	T	A	R	B	C	T	U	E	A
T	G	H	K	A	C	E	T	Y	L	E	N	E	N	N
I	K	P	T	Y	U	A	P	O	E	N	E	D	Y	E
C	Y	A	D	F	L	N	C	Y	C	L	O	L	L	M
R	T	R	N	O	L	E	Z	P	U	K	S	F	C	B
L	S	A	M	G	E	O	M	E	T	R	I	C	A	L

Figure 1. Word maze.

The winning team is that which first completes the structure and draws, at least, two isomers of it. This game teaches students:

- To recognize: types of carbons (primary, secondary, etc.) in the molecule, types of hydrocarbons (straight and branched chain), and structural isomers.
- To practice: nomenclature of organic compounds.
- To propose: new and more complex structures.

This resource was immediately accepted. The students enjoyed trying to "learn playing" and we enjoyed preparing more and different kind of games (listed on page 6).

Card Games. This type of game tests student's knowledge of common reactions and the reagents used on the different functional groups.

The first set of cards (Table 1) represents different structures of organic compounds that will be the starting molecule or the product molecule. A second set represents reagents and/or catalysts.

The students must play with the assigned cards and complete the equation corresponding to products from reactants. For example: to obtain product number 15, the starting molecule must be aldehyde number 10. Both are organic compounds that the students find in the first set of cards. The reagent to use is card number 9 of the second set. The winner is the person who can first lay down all of his or her cards.

This game provides students with practice with the nomenclature of organic compounds and with recognition of mechanisms (i.e., alkene addition, free radical substitution, and nucleophilic and electrophilic substitution).

Word Maze. The students are given a set of sentences that correspond to a definition or a physical or chemical property of a given family of organic compounds. These sentences are represented by a word that can be found in the square words, taking into account that the words may be horizontally, vertically, or diagonally written (Figure 1).

This game provides students with an opportunity to use of prior related knowledge, to recognize organic structures and their related names, to recognize functional groups, and to correspond functional groups and physicochemical behavior An example word maze follows.

Solve the word maze using the following clues. (Answers are in parentheses).

1. Characteristic suffix of alkenes. (ene)
2. Name of the isomers that can exist due to the nature of the σ–π double bond. (geometrical)
3. Acetylene contains what type of .carbon–carbon bond. (triple)
4. Planar and cyclic unsaturated hydrocarbons whose typical reaction is electrophilic substitution. (aromatic)
5. Distinctive prefix of 1,4-disubstituted aromatic compounds (para)
6. Group name of $C_6H_5–CH_2–$. (benzyl)
7. Saturated hydrocarbon containing five carbon atoms which, in high concentration, has narcotic effects on humans. (pentane)
8. Characteristic suffix of alkanes. (ane)
9. Group name corresponding to the C_6H_5 formula. (phenyl)
10. Name of the olefin that stimulates the root growth. (ethylene)

There are seven other words in the square. Try to find them and write a definition for each one. (methyl, acetylene, meta, cyclo, alkyl, ortho, isomerism)

Crossword. Complete this crossword (Figure 2) taking into account the following clues,

1. Name of the conversion process of a primary alcohol into an aldehyde by a dichromate ion addition. (oxidation).
2. Name of a reagent very useful in addition reaction with carbonyl compounds to obtain alcohols. (Grignard)
3. Trivalent element which is present in amines, amides, and nitriles. (nitrogen)
4. Straight-chain alkane containing six carbon atoms. (hexane)
5. Carbon–oxygen double bond that occurs in aldehydes and ketones. (carbonyl)
6. The most important reaction of alkenes. (addition)
7. Substitution reactions that transform alkyl halides into alcohols, ethers, amines, etc. (nucleophilic)
8. Addition reaction of hydrogen to the double bond that transforms alkenes to alkanes. (reduction)
9. Organic compounds that have an oxygen atom bonded to two carbon atoms. (ethers)

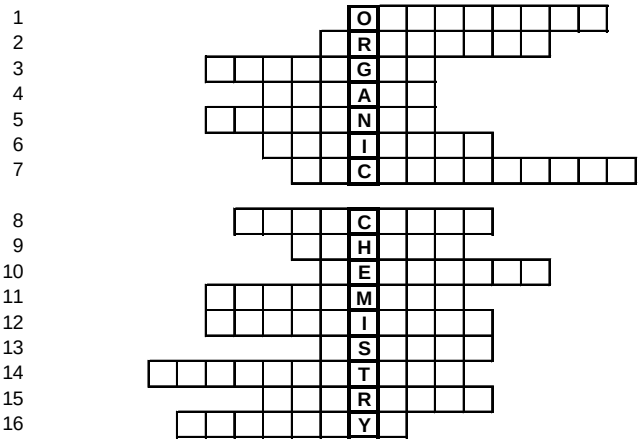

Figure 2. Crossword Puzzle.

Table 1. Number of Correct Answers Obtained on the Questionnaire After Using Games

Number of students	Number of correct answers
43/96	20
18/96	15
15/96	12
12/96	10
8/96	5

Table 2. Student Opinions of the Games Presented to the Organic Chemistry Class

Game	Number of students with a favorable opinion
Magic pencil	92
Crosswords	89
Cards	87
Dominos	75
Word maze	72
Organic structure generator	63
Riddles	48
Hidden phrase	39

10. Kind of alcohol that cannot be oxidized without the destruction of their carbon skeleton. (tertiary)
11. Name of the organic compound that results from the reaction between Benzoyl chloride and ammonia. (benzamide)
12. Type of atom group that occurs in many molecules and which gives them a characteristic chemical reactivity. (functional)
13. Organic compounds that result from the reaction between an alcohol and an acid. (esters)
14. Reaction that alcohols undergo to form alkenes. (dehydration)
15. The group contains in alcohols. (hydroxyl)
16. Functional group contained in acids. (carboxyl)

Results

We introduced the students to the games described above before concluding the topic of the nomenclature of simple organic compounds. We separated our 96 students into several groups and we gave each group a different game to be solved in class. This alternate teaching/learning methodology allowed them to work together, have a lot of interaction, assess their own learning, and it promoted open-ended discussion.

After three weeks, we gave the students a new questionnaire. This questionnaire was used for evaluation. It contained twenty questions about the nomenclature of hydrocarbons, functional groups having multiple bonds, and isomerism. The student results are listed in Table 1. More students gave correct answers to the questionnaire after we introduced games to the class. When we asked the students why they thought they had improved their performance, the majority stated that they had found the games a more amusing way to study and to relate concepts. The small amount of students who did score well admitted that they had not studied enough.

At the end of each chapter, a new questionnaire was presented and our students' performance was tested. The maximum number of correct answers (20) was achieved by 92 % of the students (88 students) after 10 weeks in which all the basic contents of the class (nomenclature, reactions, and syntheses of organic compounds) were studied. After the second midterm, we asked our 96 students to answer a survey to find out their opinion of each of the games that they had used. The results are shown in Table 2.

It is evident that students preferred those games that were more entertaining to those that demanded more effort and concentration.

The students benefited from the games in several ways. After a twenty-week period, the students:

- participated actively in class, especially working in groups,
- attended class regularly,
- practiced active reading and produced questionnaires about the topics they read,
- tried hard to improve their dialogue with us about course-related concepts,
- showed increased motivation in searching for information and greater effort in developing new ideas.

Conclusion

Our experience is one of many experiments that are periodically published by authors who resort to games [2] and to activities organized around small groups of students to generate cooperative learning [3] for the teaching and learning of chemistry. These kinds of activities were extremely gratifying to us and to our students, and this experience allowed us to confirm that the emotional approach plays an important role in the teaching/learning process, because both activities (teaching and learning) are highly emotional [4]. We constantly promoted a permanent dialogue, giving the students the main role in class. By the end of the three-month period, the communication levels became very interpersonal, characterized by constant interchange and growing interrelation between teachers and students.

We were able to demonstrate to our students that learning is a process that requires effort and continuous assessment, but it can also be pleasant, and apparently, a "hard" subject like chemistry can become more interesting and fun in a relaxed atmosphere.

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References and Notes

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