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In the Classroom

# An Essay Assignment for Organic Chemistry Courses

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*The assignment was designed to stimulate the interest of students in the role of organic chemistry in the world.*

An essay assignment suitable for large introductory organic chemistry courses is described. Students were asked to write four-to five-page essays about any organic compound of their choosing that was in the news recently, was used widely, or had some social significance. The assignment was designed to stimulate student interest in the role of organic chemistry in their lives, to help them make connections between classroom information and the "real world", to have them practice their writing skills, to teach them to use the library and other sources of scientific information, and to help them improve their grades by evaluating them with an instrument other than an exam. Techniques used by the instructor to manage the burden of grading a large number of essays are described.

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## Introduction

Most organic chemistry instructors have heard their students complain that the material they learn is irrelevant to their "real lives." Apparently many students feel that organic chemistry is a hurdle they must overcome in order to achieve their other goals (usually, medical or pharmacy school), rather than a body of knowledge which will serve them well in the future. In order partly to address this sentiment, I asked the ca. 120 students in first-semester introductory organic chemistry (spring 1996) to write a five-page essay about an organic compound of their choice that was in the news recently, was used widely, or had some social significance. The experiment described here was largely successful. A similar assignment, but with assigned topics in an introductory chemistry course, was described by Pyle and Trammel in 1982 [1].

## Purposes of the Assignment

The assignment was designed to stimulate the interest of students in the role of organic chemistry in the world. I thought that if students realized the relevance of organic chemistry to their lives, they might become more excited about the topic. To encourage their interest, the students were given permission to write about *any* organic compound they chose.

The assignment was meant to encourage the students to make connections between the material they learned in class and "real world" situations. Knowledge that is well-connected and integrated with other knowledge is most likely to be retained by students. I also hoped that the students would use their newly gained knowledge to understand issues that are of wide public concern.

The assignment forced the students to write. Writing is an art that is ignored in most science courses, and many science students think that it is not important for them to be able to write well [2]. Of course, it *is* important, as any professional scientist knows, but it must be admitted that the traditional methods of testing in science courses, with their emphasis on *symbolic* expression and factual knowledge, give this impression. I hoped that the assignment might help to impress on students the importance of writing well, thus better preparing them for careers in academia or industry.

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The assignment was meant to teach the students how to use the library, the World Wide Web, and other resources to gather scientific information. Without this assignment, our students would have been juniors or seniors before having to wade into the scientific literature.

Finally, I wanted to give the students an opportunity to perform well on an evaluation instrument other than an examination. One of the students' most common complaints about introductory organic chemistry was that their grades were completely dependent on examinations; graded homework was precluded because of staffing considerations. I hoped that the assignment would give the students an opportunity to earn some improvements in their grades.

The assignment was made on the first day of class and collected one week before the end of the semester, so the students had the entire semester to choose, and gather information about, their compound. Throughout the semester I would occasionally mention compounds that had just appeared in the news. Examination and lecture schedules were not altered from what they would have been without the assignment.

## Grading Criteria

The assignment was graded 50% on content (scientific and nonscientific), 30% on clarity of expression, including spelling and grammar, and 20% on "originality and relevancy." The content part of the students' grades depended largely on how well they applied class material (structure, stereochemistry, spectroscopy, reactivity) to their discussion. At a *minimum*, the essay had to include the compound's chemical structure and the reasons that the student chose to write about it. The discussion of medical, social, and other issues surrounding the compounds was also encouraged. To provide motivation, the assignment counted as much toward the final grade (one sixth) as a conventional examination. The criterion of "originality and relevancy" was created in order to discourage all of the students from writing about the same compound.

## Essay Results

I was gratified by the quality of the essays and the obvious effort that many of the students put into their work. The 72 different compounds chosen by the 117 students represented many different areas of organic chemistry (Table 1). There was, as

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**TABLE 1.** Essay topics (number of essays, if greater than one):

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|---|---|---|---|
| Acetaminophen | Acyclovir | Agent Orange | Aspartame |
| Batrachotoxin | Buckyballs (2) | Caffeine (3) | Camphor |
| Carbon monoxide | CFCs | Chlorophyll | Chloroquine |
| Chlorpyrifos | Chromium picolinate | Citicoline | Creatine |
| Dioxin (2) | Dopamine | Ecstasy (2) | Ephedrine (2) |
| Estrogen (2) | Fatty acids | Fenfluramine | Fluoxetine (Prozac) (4) |
| Folic acid | Heparin | Hexane | Ibuprofen |
| Itraconazole | Ivermectin | Levodopa | Lorazepam (Ativan) |
| LSD (3) | Melatonin (4) | Methyl bromide | Methyl chloroform (3) |
| Methyl isocyanate | Methylphenidate (Ritalin) (4) | Morphine | MSG |
| Mustard gas | Nicotine (4) | Nitroglycerin | Norgestrel (Nordette, oral contraceptive) |
| Nornicotine | *o*-Chlorobenzylidenemalonitrile (CS chemical warfare agent) | Polycyclic aromatic hydrocarbons (PAH) | Phenylbutazone |
| Polycarbonate resin (Lexan) | Polyethylene | Prednisolone | Progesterone |
| Propane | Sarin | Serotonin | Stanozolol (anabolic steroid) |
| Sucrose polyester (Olestra) (11) | Sumatriptan (Imitrex) | Tacrine | Tamoxifen |
| Taxol (6) | Tetracycline | Tetrodotoxin | Thalidomide (4) |
| THC (3) | Vancomycin | Vinyl chloride | Vitamin A |
| Vitamin C | Vitamin E (3) | Warfarin | Zidovudine (AZT) |

expected, an emphasis on pharmaceuticals due to the large number of premedical and prepharmacy students in the class. The most commonly chosen topic, however, was Procter & Gamble's sucrose polyester fat substitute, Olestra[1]. Almost 10% of the students chose to write about Olestra, whose FDA approval was often in the news in the spring of 1996 when this assignment was given. Six students wrote about Taxol, the new antineoplastic drug, possibly because the early conflicts between environmentalists and cancer patients over this compound provided good fodder for essays. Four essays each were written about nicotine; the controversial medicinal

[1] Olestra is a registered trademark of Proctor & Gamble Company.

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drugs fluoxetine (Prozac[2]), methylphenidate (Ritalin[3]), and thalidomide; and the hormone melatonin. Other students wrote about chemical warfare agents, solvents, polymers, food additives, nutrients, illegal recreational drugs, industrial chemicals, natural and unnatural toxins, and of course many medicinal drugs. Several important compounds (cocaine, aspirin, cholesterol, carbon dioxide) were noticeably absent from the list; the requirement for "originality" probably frightened the students away from these topics. It was encouraging to see that roughly equal numbers of students chose to write about beneficial, harmful, or benign compounds, especially considering the natural predilection to focus on controversial topics.

If the most important aim of the assignment was to encourage the students to notice the importance of organic compounds in their lives, then it certainly achieved its goal. Many students wrote remarkably personal essays about the roles that organic chemicals had played in their lives. For example, a friend of one essayist committed suicide while under treatment with Prozac, while the grandmother of another suffered from Parkinson's disease and was being treated with levodopa. One student noticed that methyl chloroform was being used to clean the oven in the deli where he worked, and he was appalled to discover that the workers using it were ignorant of its dangers and lacked protective equipment. Another student wrote about CS (chemical warfare) gas, of particular concern here in central Kentucky because of the army's plans to build a chemical weapons incinerator nearby. Another student was comforted to learn that MSG was a relatively harmless substance. A few of the students who wrote about "Ecstasy" (MDMA, 3,4-methylenedioxymethamphetamine) were quite strident in their views that it should be legalized.

The scientific content of the essays varied in quantity and quality. Students who have completed most of only one semester of organic chemistry cannot be expected to write essays with brilliant scientific content, and I did not expect to see any. However, I did expect the students to do their best to apply classroom material to their topics. Some of them clearly made an effort to do so. For example, some of the students who discussed Ritalin pointed to its two stereocenters and discussed their implications for therapy. Students who wrote about serotonin were able to compare its structure with tryptophan and various other biologically important indoles. It was encouraging to see many

[2] Prozac is a registered trademark of Eli Lilly and Company.
[3] Ritalin is a registered trademark of Ciba-Geigy Corporation.

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students try to apply their classroom knowledge, even falteringly, to their topics. Unfortunately, a common approach was to abandon all chemical discussion and concentrate on the more easily understood biological aspects. Given the students' limited knowledge of organic chemistry partway through their first semester, this was a natural inclination, but in the future I plan to emphasize more strongly that the students' grades depend on their incorporation of classroom knowledge into their essays. (I also understand that many of these essays were written for both organic chemistry and biology classes. This may explain the large amount of biology in the essays.) The chemistry content of the essays might also increase if this assignment were given in the second semester of introductory organic chemistry.

One often hears complaints of "Johnny can't write," so I was expecting the quality of writing in many of the essays to be poor. To my great surprise and pleasure, most of the essays were a pleasure to read. There were only a handful of essays in which the writing was an impediment to understanding. Evidently, the students who take introductory organic chemistry at this state university are perfectly capable of writing well when they are convinced that it is important to do so. Other instructors who have given writing assignments have observed similar phenomena [3]. The director of the University of Kentucky Writing Center, Dr. Gail Cummins, suggested that the quality of the writing may have reflected the fact that the students were allowed to use whatever writing format or style with which they felt most comfortable.

Students were encouraged to bring rough drafts of their essays to me so I could help them find chemical issues that they could address, and many came to me to discuss their essays. They usually had one of two questions: either, "Where can I get information?" or, "I have all this information, what do I do with it?" The first question could usually be answered by opening the *Merck Index* or suggesting that the student visit our librarian. The second question required more time. Usually I walked the student through the information that he or she brought, asking questions about the compound and suggesting lines of further inquiry. Students who took advantage of my offer of help naturally tended to produce more scientifically sound and better written essays, no matter how difficult their topic. (They may have produced better than average essays anyway, as they were probably more motivated than most.) I am sure that these students learned more from the writing exercise than they would have done otherwise. Still, there were many students who did not ask for help but nevertheless produced excellent essays, and even some of those who came for help wrote poor ones.

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A requirement that the students write and turn in *two* drafts of their paper would definitely increase the pedagogic value of the exercise, although it would of course, increase the instructor's workload. Students who brought badly written essays to me were encouraged to go to the Writing Center.

Judging from the number of students who asked me for directions to our chemistry and medical libraries, many students must have been using these facilities for the first time. The *Merck Index* and the *Dictionary of Organic Compounds* were popular resources for essays, as were inserts published by pharmaceutical companies. I was surprised to learn from the references that a large number of students used the World Wide Web to find most of their information. In fact, some students used the Web to the complete exclusion of more conventional sources. A requirement that at least some sources be from the peer-reviewed literature has been instituted (see below).

One area where the essay assignment may have been less successful was impressing on students the importance of writing well about science. The students seemed to perceive the essay assignment more as an opportunity to improve their grades (for which most were grateful), than as an exercise to help further their education. In fact, to my surprise, several of my top students resented the extra work, thinking it inappropriate that an essay had been assigned in a science class. (I did my best to disabuse them of this notion.) A more thorough and consistent emphasis on writing throughout this and other courses will probably be necessary to convince our students that writing well is an essential part of science.

## Grading the Assignment

When I told my colleagues about this assignment, the most common reaction was to warn me about the amount of work it would generate for me [4]. In fact, with the help of the usual number of teaching assistants (ca. four TAs for ca. 120 five-page essays), the essays took no longer to grade than a conventional examination (most of one day).

Assigning appropriate grades to the essays was much easier than I expected. It is true that grading essays is more subjective than grading questions of fact, but the higher quality essays were clearly recognizable and could be graded appropriately. (I would also suggest that grading conventional organic chemistry exams is sometimes more subjective than we realize. I cite mechanisms, which are essentially graphic essays, as

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an example.) The essays were divided into five bins according to both form and content, and all essays in each bin were assigned the same grade (excellent, A+, 95%; very good, A/B, 75%; merely adequate, B/C, 60%; not good, C/D, 45%; poor, F, 30%). Essays in which students wrote clearly but only had the minimum amount of chemistry (compound structure) and a lot of biology were assigned to the “merely adequate” bin. On the other hand, essays whose authors clearly made an effort to apply classroom concepts such as stereochemistry, reactivity, etc. to their topics were assigned to the “very good” or “excellent” bins, depending on the quantity and the accuracy of the chemistry. Those essays which were written badly were assigned to the “not good” or “poor” bins; the chemistry in these essays was usually as bad as the writing. Essays which seemed slightly more or less deserving than the others in their bin were assigned slightly higher or lower grades accordingly. To ensure consistency among the graders, essays on identical topics were distributed among different graders, and the grades were then compared and normalized by all. After this had been done a few times, all essays on one topic were read by a single grader. I also took the trouble to glance through the TAs’ work, and I generally concurred with their grades. Each paper required about five to ten minutes to grade. Written comments were usually very short and to the point: “Good!”, “No!”, “Show structure!”, “Why?”, or “Interesting!”. Misspellings, run-on sentences, and the like were marked when they became distracting or an impediment to understanding.

Clearly the amount of work involved in grading the essays will vary tremendously depending on how much effort the instructor wishes to invest. For example, instructors who want to correct every spelling error or solecism will spend more time grading. Anyone using this assignment will have to find the right level of effort for themselves. Instructors with large classes and teaching loads cannot afford to spend as much time on each individual essay as instructors with smaller classes and lighter loads. I can only attest that what I considered to be a conscientious job of grading was not unduly burdensome to me.

It was simple to tell when students were merely parroting their sources without understanding what they were saying, because the basic concepts I was expecting students to refer to are generally not discussed explicitly in the primary literature. Credit was given when students explained concepts in their own words. Students who tried to apply classroom concepts but did not do so properly or well were given some credit for trying. For example, one student tried to explain how an NMR experiment

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was used to determine the enantiomeric excess of synthetic nornicotine, but she confused the concepts of “diastereomer” and “enantiomer”. She would have earned a higher grade if she had explained it correctly, but she still earned a higher grade than she would have done if she had not tried to explain the concept at all. Other instructors, of course, may have a different grading philosophy.

Some topics lent themselves more readily to explication than others. For example, students who chose to discuss Taxol often found themselves floundering if they tried to discuss its total synthesis. Its semisynthesis, on the other hand, was easier for them to understand. The particular difficulty of some topics such as paclitaxel may have hurt some students’ grades somewhat; this was an unfortunate but necessary byproduct of giving the students complete freedom to choose their own topics. In order to partially compensate for this, essays whose authors had unwittingly bitten off more than they could chew were graded more leniently. I think it worth emphasizing, however, that some students wrote brilliantly on difficult topics, while others wrote poorly on easy ones. Quality was clearly recognizable, no matter what the topic. It is also worth restating that all students had the opportunity to ask me for some direction in writing their essays.

The overall quality of the papers was demonstrated by their average score of B+ (cf. an overall exam average of C+). Most students were satisfied with their grades. A handful of dissatisfied students came to me for an explanation. They usually understood the reasons for their grades after I walked through their essays with them.

## Modifications

Some aspects of the assignment clearly needed some improvement after it was first given in 1996. I was not pleased that many students obtained most or all of their information from the World Wide Web in 1996, so in 1997 I instituted a requirement that at least two references from the peer-reviewed scientific literature be used. The requirement was enforced by making “quality of references” worth 10% of the students’ grades (at the expense of “originality”, which was reduced to 10%). Students who did not use two peer-reviewed references were docked 5 or 10 points. (Introductory textbooks and encyclopedias did not count as peer-reviewed references. Monographs and advanced textbooks were borderline cases that had to be evaluated individually.) More emphasis was also placed on the need to incorporate classroom

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concepts into the discussion of the topic compound's chemistry to obtain a good score on content, and less emphasis was placed on the discussion of social issues. With these changes, the average grade declined slightly, from B+ to B.

Plagiarism was a more serious concern the second time this assignment was given, especially in this era of computer diskettes. All students in the 1997 course were required to sign a "plagiarism certification", stating that they had read the University definition of plagiarism, they understood it, they promised not to do it, and if they had any questions they would ask *before* they handed in the assignment. Moreover, students were told that essays from 1996 had been kept (they had), and that 1997 essays would be compared to 1996 essays on the same topics (they were). In the event, no essays were found to be plagiarized. Only one student failed to sign a plagiarism certification. (He earned a zero for the assignment.)

I considered making the assignment voluntary in 1997, but I decided against it. A voluntary assignment would certainly have decreased the amount of work required on my part, but I felt that the assignment was of sufficiently pedagogic value for all of the students that it should be mandatory.

In conclusion, the essay assignment met almost all of the goals for which it was designed. I encourage other organic chemistry instructors to use this tool in their classrooms as well.

Supplementary Information Available: HTML document explaining the assignment to the Spring 1997 students (22gr1897.htm 10.6 Kbytes).

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