

Student Perceptions of the Benefits of a Learner-Based Writing Assignment in Organic Chemistry

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The organic chemistry class at Oral Roberts University (ORU) is a two-semester lecture course of three credits per semester in which the majority of students are declared pre-medical, pre-dental, or prepharmacy majors and plan to pursue a career in the health professions. To supplement standard assessment methods of quizzes, homework assignments, and exams, various alternative methods of assessment have been introduced, one of which is a writing assignment that is the subject of this paper. In recent years, numerous articles have been published that have focused on the incorporation of writing assignments into the organic chemistry curriculum. Projects such as inquiry-based and collaborative laboratory reports, literature reviews of scientific papers, summaries of lecture notes, reviews of current events relating to chemical issues, and writing papers on pertinent chemical subjects have been introduced into the curriculum and have been reported in the literature (1–10). For seven years, students in the organic chemistry class at ORU have been required during both semesters to submit a research paper on a specific organic molecule and perform a qualitative risk assessment on the molecule chosen for study. Additionally, they must incorporate information from at least one peer-reviewed paper from the scientific literature into their project.

Purpose

The goals of the writing assignment in this course are to:

- Introduce into the curriculum a learner-based component that integrates library and online research, chemical drawing, spectroscopy, reading a peer-reviewed scientific paper, and other facets of chemistry into one assignment.
- Encourage students in health-care-related fields to appreciate the value of organic chemistry by emphasizing the practical, real-world applications of the subject.
- Encourage critical thinking by requiring students to perform either a qualitative risk assessment or an environmental analysis on a given chemical.
- Increase information literacy and the use of technology.
- Incorporate a writing component into the curriculum.

Self-Guided Written Assignment

Throughout the nation, the majority of students enrolled in organic chemistry are in a prehealth professions major (11). Many students typically regard organic chemistry as a course with minimal practical application to the medical field and one that represents a major challenge to the pursuit of professional goals. By requiring participation in a project in which students have a major interest because of their goal of entering the health professions, the research paper serves as a mechanism to motivate them in the study of organic chemistry. Incorporating a writing assignment that is related to the medical field and performing a qualitative risk assessment on a medicinal chemical facilitate

increased understanding and appreciation of the relevance of organic chemistry to the medical arena in which the students plan to serve. Performing the risk assessment helps students begin to think critically about a given molecule and reflect on the benefits as well as the risks associated with it. Requiring a research paper also provides students with an opportunity to develop their writing skills in a manner not afforded by the preparation and submission of laboratory reports, where the written material is often highly regimented and largely dictated by the outcome of the laboratory experiments. This self-guided assignment also exposes the students to scientific primary literature and involves them in an independent study that encourages them to think critically about a given chemical.

Students are encouraged to choose a chemical from either current organic research or one of environmental or medicinal application. They may select a topic of personal interest or they may choose from a list of approximately 40 options provided by the instructor. Because the majority of students enrolled in the class plan to enter the medical field, most have typically chosen to write on an organic compound such as a pharmaceutical, vitamin, natural product, or other medicinal agent. Frequently, students have chosen to write on a medication of personal interest that they or a family member are currently taking. Other areas students have selected are polymers, nanotechnology, and environmental toxins. During the second semester all students are required to write on a specific pharmaceutical and must provide circumstances under which the pharmaceutical would be either prescribed or contraindicated.

Because concepts introduced during the first semester of the course are rudimentary yet requisite for further understanding, the first-semester requirements for the paper are less demanding than the requirements for the second-semester paper. During the second semester, students are encouraged to write on a topic or structure that requires more in-depth understanding than is possible for a beginning organic chemistry student; students are instructed not to write on simpler molecules such as aspirin and acetaminophen. Examples of molecules chosen are isotretinoin, hydrocodone, paclitaxel, and morphine. Several students who are planning to enter a specialized medical area have written on drugs pertinent to their chosen area of specialization. For example, one student planning to become an obstetrician researched oxytocin.

Over several semesters two shorter papers have been assigned when topics of current interest or suitable content have been deemed appropriate for the level of the class. During the second semester of the course—for a two-year period—students have submitted two papers: one on a specific pharmaceutical, and a second paper on a toxic chemical.

Requirements of the Research Paper Assignment

Written instructions describing the assignment are given to the students at the beginning of the semester. Examples of

two copies of instructions, with suggested topics, are included in the online supplement.

The paper must incorporate these elements:

- A structure generated in a chemical drawing program
- Identification of all functional groups and tetrahedral stereogenic centers
- Synthesis (or partial synthesis), properties, and uses
- Infrared spectrum (NMR in second-semester paper)
- Analysis of health and environmental effects
- Risk–benefit analysis
- Correct grammar, spelling, punctuation, and sentence construction
- Information from a peer-reviewed, scientific paper
- MLA citation style
- List of references (one must be from a primary source)

Students are asked to use a chemical drawing program such as ChemSketch (available as a free download from ACD/Labs; see ref 12) to draw the molecular structure of the molecule being studied. Because incorporation of structures using the ChemSketch drawing program is a requirement for reports in the organic chemistry laboratory course, students will have already been introduced to this program earlier in the semester and presumably can use it with facility by the time the first research paper is due toward the end of the semester.

Students in both semesters are required to identify all functional groups and stereogenic centers in the organic molecule being researched. The course textbook by Solomons and Fryhle, *Organic Chemistry* (13), covers functional groups and infrared spectroscopy in a beginning chapter, so this portion of the assignment can be accomplished relatively early during the semester.

In addition, students are required to research the literature to obtain an infrared spectrum of the structure being studied and are required to identify major characteristic absorption peaks in the spectrum. If they cannot obtain a literature infrared spectrum, they are required to predict the peaks from tables in the text or other sources. During the second semester, students also are required to research the literature to obtain an NMR spectrum of the compound of interest, or, if the spectrum is unavailable, they are asked to predict the major chemical shifts in the NMR spectrum. A detailed analysis of the NMR spectrum is not required.

Students must also research the health and environmental effects of the molecule or molecules they select to study. In the case of a pharmaceutical, they must evaluate the drug in terms of potential risk, identify possible side-effects, and include a qualitative risk assessment in the paper. This feature of the assignment gives future health-care professionals exposure early in their career path to possible drug interactions and contraindications of various pharmaceuticals. Students are specifically instructed to answer the question, “Would you prescribe this medication to a patient, and under what circumstances would you choose another pharmaceutical?” This aspect of the assignment enables future health-care providers to begin to think critically about the chemical and thoughtfully consider the decision-making process involved in prescribing various pharmaceuticals. With chemicals

that pose an environmental risk, students must discuss potential risks of exposure to a given molecule.

In addition, students must research the physical and chemical properties of the substance under study as well as its major uses. Typically, students use the *Merck Index* (14) and various other online resources to identify the physical properties of many of the compounds. Depending upon the complexity of the molecule being studied, students must locate or predict a synthesis (or partial synthesis) of the molecule. The students are to incorporate results from an original, peer-reviewed article into their paper; this facet of the assignment provides an early introduction to scientific literature and begins to foster the ability to critically evaluate a scientific article. Students are also required to include citations to each reference used in the paper, which gives them experience in the proper use and citation of research sources. The instructor tells students that the paper should be written creatively and not simply be an encyclopedic listing of the required information.

Evaluating the Papers

The research paper represents 10% of the overall course grade and is equivalent to a one-hour examination. Assessment of the paper is done using a rubric designed by the instructor; it includes five levels of performance: exemplary, competent, acceptable, unacceptable, and not attempted. Specific areas of assessment are: structure; stereochemistry and bonding; spectra; synthesis; properties and uses; health and environmental effects; risk benefit analysis; references and documentation; writing; and presentation. The rubric is provided to students on the local intranet and must be included as an attachment to the paper. Examples of two rubrics, which include detailed breakdowns of how the assignment is graded and the weight given to each category, are available in the online supplement.

The syllabus for the course establishes guidelines for plagiarism; if a written assignment is determined to have been plagiarized, the grade for that assignment is zero. Usual measures are used to check for possible plagiarism, such as observing vocabulary that seems to exceed a student’s level of expertise, changes in font, misplaced or incorrect references, and improper placement of text. Phrases that seem inconsistent with a student’s usual writing style can be searched for online by typing the phrase in quotation marks. Recently, our institution has contracted with Turnitin, an online plagiarism prevention program; students are now required to submit their papers to this Web site, which uses many databases to check for plagiarism.

Students’ Self-Assessment of the Benefits of the Paper

No formal rigorous statistical evaluation and assessment of writing an organic research paper has been conducted. Over a period of four semesters and one summer session, however, students were given an informal survey and invited to answer the following questions, on a scale of 1–5, with 5 representing yes, most definitely; 4 meaning yes, 3 meaning neutral, 2 representing no, and 1 not at all.

1. Did the research paper increase your knowledge of organic chemistry?
2. Did the research paper increase your interest in and/or appreciation of organic chemistry?

Table 1. Distribution of Student Responses to Informal Survey Questions Concerning Students' Perceived Benefits of the Research Paper

Survey Questions 1–5	Students Selecting This Score for Response, % (N = 104)					Responses of 4 or 5, % (N = 104)
	5	4	3	2	1	
Did the research paper increase your:						
Knowledge of organic chemistry?	26	41	24	7	2	67
Interest in and/or your appreciation of organic chemistry?	45	32	15	6	2	77
Knowledge of infrared spectroscopy?	17	27	30	17	9	44
Knowledge of NMR spectroscopy?	12	25	35	14	14	37
Knowledge of organic synthesis?	25	32	21	16	6	57

- Did the research paper increase your knowledge of infrared spectroscopy?
- Did the research paper increase your knowledge of NMR spectroscopy? (second-semester question)
- Did the research paper increase your knowledge of organic synthesis?
- What areas of organic chemistry listed below were impacted most by the research paper?
 - Spectroscopy
 - Synthesis
 - Risk assessment
 - Medical and pharmaceutical
 - Toxicology
 - Other topics
- Are there other areas of organic chemistry in which the research paper stimulated your interest in and/or desire for further study?

A total of 104 students of the 125 students who submitted the research paper responded to the survey. Table 1 reports the results of those responses. The data show strong agreement that the research paper had increased students' knowledge of and interest in or appreciation of organic chemistry. The surveys also indicated that the majority of students believed that the paper increased their knowledge of organic synthesis. A significant number of students also felt that their knowledge of spectroscopy had increased, although the number was lower than the perceived increases in the other areas surveyed.

Predictably, considering the composition of the class, the responses to question six indicated that the areas most affected by writing the paper were medical and pharmaceutical; toxicology; and risk assessment. Overall, student comments in the informal survey were quite positive and encouraging; several students indicated that the paper had increased their awareness of the importance of chemistry and had helped them to apply concepts to real life. One student commented, "After completing the research paper on a pharmaceutical, I wanted to do other pharmaceuticals." Another student stated, "It was nice seeing organic chemistry in action", and one stated, "It stimulated interest in how certain compounds are harmful."

Summary

In summary, the research paper writing assignment in organic chemistry has proven to be an effective tool in the usual teaching methods employed. This point has been borne out by the overall perception by students enrolled in the class, a significant percentage of whom agreed that the paper has increased their interest and understanding of this seemingly complex

subject. The paper offers students early exposure to chemical literature, increases their familiarity with a chemical drawing program, enhances their understanding of organic spectra, and gives them a greater appreciation of the molecular structure and health effects of the organic chemical being studied.

Moreover, by requiring students to perform a qualitative risk assessment and study the health effects of a particular chemical, writing the paper encourages students to reflect critically upon the advantages and disadvantages of various pharmaceuticals and other chemicals. Requiring a written research paper also fosters good writing skills, which helps students in the short term as they prepare to write a senior paper on their own laboratory research, and also assists them in the long term, as they begin to pursue their individual professions. By allowing the students to study an organic molecule of their choice, one should expect that students will be stimulated to become more actively engaged in the study of organic chemistry and gain a greater appreciation of its practical applications.

Literature Cited

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Supplement

Example instructions for students and assessment rubrics