Chemistry for Non-Science Majors: What Do They Need to Know, And How Do We Teach It To Them?

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Abstract

There are a variety of opinions on what non-science majors should get out of their science courses. Consider that many of our non-science majors will gain a great deal of control over our scientific establishment and its activities in their professional capacities as legislators, public administrators, jurists, business executives, and so on. Most will give their opinions on some scientific and technological issues as voters at the polls. What do we want to communicate to these individuals while we have the opportunity? This paper presents the argument that chemistry courses for non-science majors should be about more than science literacy, a term that means different things to different people. They should also help our non-science students develop critical reasoning skills needed by citizens living in a technological society. Furthermore, our teaching methods should make sense in view of the objectives. We offer two courses in chemistry for non-science majors at Grand Valley State University. One is a standard lecture course. The other is a guided-inquiry course with laboratory. Both present chemistry on a need-to-know basis in the context of societal issues. We have been assessing the two courses to determine their relative merits in improving scientific literacy and in promoting critical reasoning skills. Our results will be discussed.

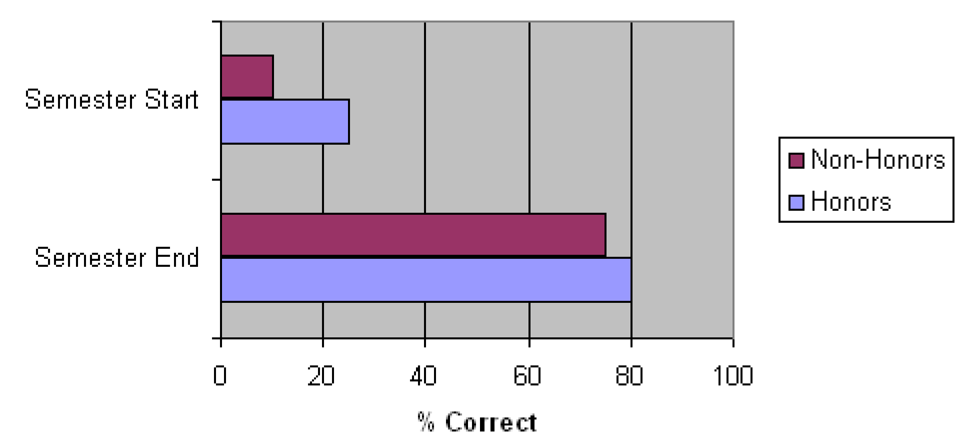
It is certain that many of our non-science students will gain some control over our scientific establishment and its activities in their professional capacities as legislators, public administrators, jurists, business executives, and so on. Most will give their opinions on some scientific and technological issues as voters at the polls. What do we want to communicate to these individuals while we have the opportunity? It seems that a chemistry course for non-science majors should be about more than science literacy. In view of the important influence some of these students may have eventually, such a course should help them develop the critical reasoning skills needed by citizens living in a technological society. Furthermore, our teaching methods should make sense in view of our objectives.

We offer two courses in chemistry for non-science majors at Grand Valley StateUniversity. One is a lecture course offered in several sections of 30 to 80 students each. As an experiment, the lectures in one section are supplemented with guided-inquiry group projects and workshops that address important scientific concepts.The guided-inquiry projects are designed to follow the learning cycle pattern. Data is presented which the students are invited to process and analyze. The students are then asked to formulate hypotheses and models that explain the data. Finally, the students are asked to test their hypotheses and models, revising them as necessary.

The second chemistry course is for honors students only and uses cooperative-learning techniques such as guided-inquiry group projects and laboratories exclusively. It is offered in several sections of 24 students each. Both courses present chemistry on a need-to-know basis in the context of societal issues. We are in the process of assessing the different learning formats to determine the relative merits of cooperative learning techniques in improving scientific literacy and in promoting critical reasoning skills. Here are some of our results.

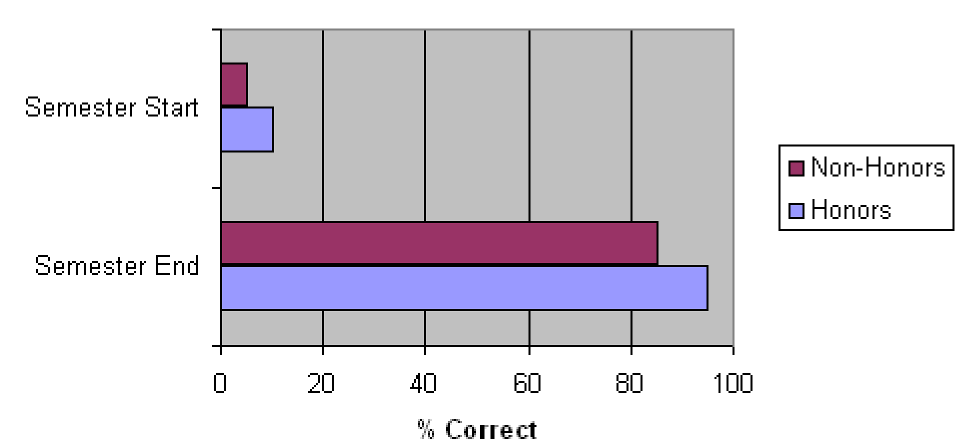
Who are our non-science majors? At the start of each semester, all students fill out extensive questionnaires that explore how much they remember from the high school science courses they may have taken, their attitudes toward science, and their preferred learning styles. Almost all students have had at least one science course in high school. Many have studied several subjects, including biology, chemistry, physics, and group science. Most have a rough idea of the goals of science and of the scientific method, although many confuse science with applied science and engineering.

Figure 1: What are the defining characteristics of a scientific model?



In general, the honors students have better communication skills than the non-honors students. They read more, and they seem more motivated to succeed. Also, they retain more facts and ideas from their high school science classes. However, both honors and non-honors students arrive with serious misconceptions based on prior experience and education. For instance, most see energy release in a chemical process as being like breaking an egg. Break the eggi.e. a chemical bondand out pours the energy. This leads to great confusion in matters related to thermodynamics and chemical bonding. Other common misconceptions about scientific issues have been described (1).

Figure 2: Where does the energy released in a combustion reaction come from?

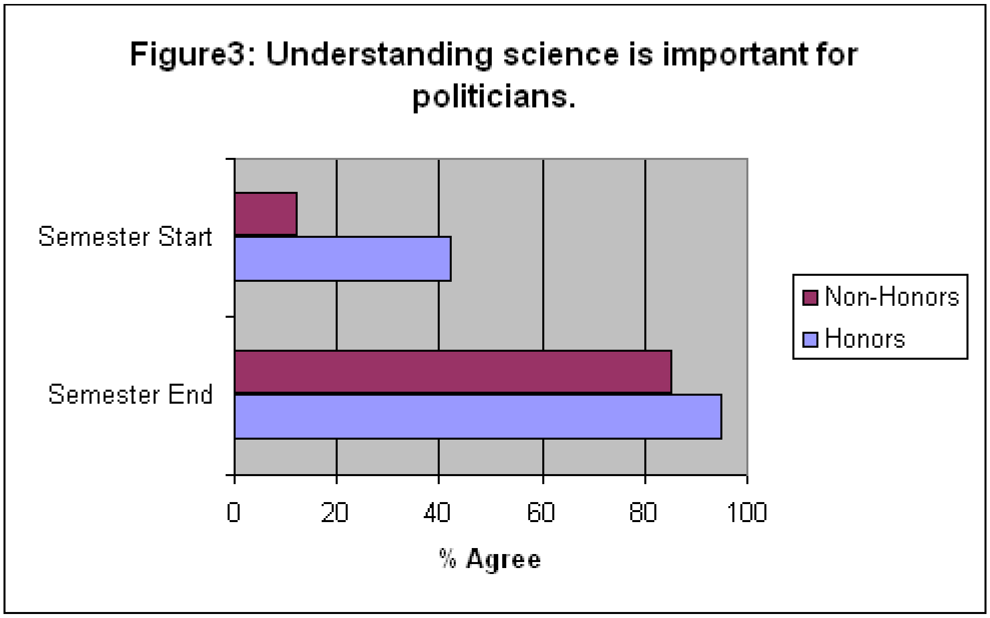


There is little difference between the attitudes of honors and non-honors students toward science. Many say they dont like to study science, and a significant number see little professional value in understanding science. Oddly, most claim to see personal advantages to being science literate.

The honors students claim to learn best with a variety of teaching methods, whereas almost all of the non-honors students claim to prefer listening to lectures. This may reflect a lack of experience on the part of the non-honors students. Honors classes usually employ cooperative-learning methods while the non-honors courses usually do not. It may also reflect unwillingness on the part of some students to accept the responsibility for their own progress that goes along with active learning. In any event, the non-honors students require a period of familiarization before they feel comfortable with cooperative learning.

I dont think many of us require our chemistry majors to memorize facts that can be found in reference books, and we certainly would not require this of non-science majors. Nevertheless, it is amazing how many of our non-science majors claim to have been asked to memorized the periodic table in high school. Predictably, they derived little benefit from this. Few can remember the details. None understand the table other than as a convenient collection of facts. For most students, it seems that high school science is mainly about forgettable facts and has little to do with memorable concepts. This is not what we want our students to remember about chemistry.

What do our non-science majors need to know? Our students will be called upon eventually to make decisions about technological issues, and we should help them lay the groundwork for sound judgment in these matters. For instance, students should be helped to address the serious misconceptions that may lead to confusion in understanding scientific concepts. While our students have some appreciation of the scientific enterprise, they need to appreciate the difference between science and engineering. This might help them understand the adversarial nature of science and why there is almost never unanimity on scientific issues.



Foremost, we should help our students learn critical thinking skills. If we want them to make careful and informed decisions about the technological issues confronting them, they must learn to analyze complicated questions and evaluate the risks and benefits of potential courses of action. Even science majors would be best served with less rote memorization of facts and more training in critical thinking.

How do we teach our students to correct their serious misperceptions and learn critical thinking skills? It is estimated that about 80% of classroom time is now spent in teacher talk (2). After all, we were trained this way, so why not lecture to our students? Several serious shortcomings of the lecture method have been identified (3,4). The lecture method assumes knowledge can be efficiently transmitted directly from the teachers mind to the students mind. This may be true if we are communicating facts but not if we are asking students to understand concepts.

For instance, a recent study showed that the best lecturing at the finest institution may leave students more confused about chemistry at the end of the semester than they were at the beginning (5). One way of thinking about this is that students may come to class with ideas that conflict with what they will be asked by their instructor to understand and remember. If they are not challenged to test their counterproductive beliefs and construct their own knowledge base, they can be left holding two conflicting and confusing sets of ideas in mind, what the instructor wants them to remember and what they actually believe to be true.

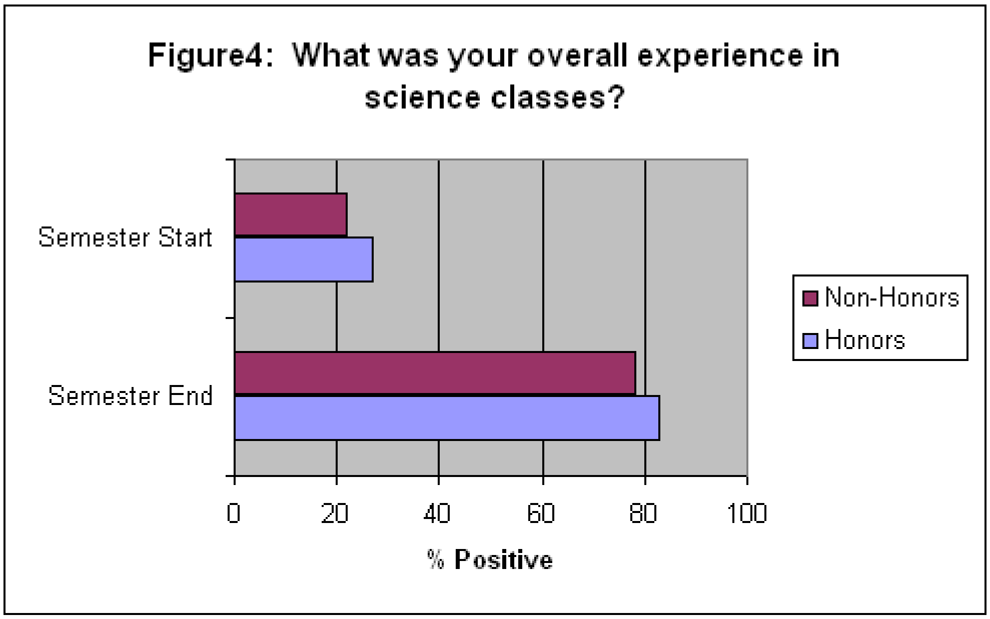
Lecturing takes no account of a students preferred learning mode. Indeed, learning takes place, if at all, after the lecture as our students try to make sense of their notes, solve homework problems, and so on. This more often than not means that students will focus on algorithms used to solve specific kinds of problems. In the course of this rather impersonal and mechanical process, students develop negative perceptions of science and fail to see the relevance of the material presented to them (6,7).

Students learning styles are likely to be different from the instructors and may be better addressed with cooperative-learning methods (8). Indeed, we can all employ more than one mode of problem solving (9), and we can allow for this best with such methods. The problems mentioned so far can be overcome by giving students the opportunity to challenge their misconceptions and cooperate in the construction of their own knowledge base (10,11). The pedagogical basis of cooperative learning has been reviewed in detail (12).

What are the results of our evaluation of cooperative learning methods? At the end of the 2003 Winter semester, our students were tested on their understanding of the same important scientific concepts that had been explored in the preliminary tests administered at the beginning of the semester. The students again filled out questionnaires concerning their attitudes toward science. A few students voluntarily submitted to follow-up interviews by faculty other than the course instructor in which their understanding of the course material and their attitudes were explored in depth.

We found that students who attended lectures featuring supplemental cooperative-learning activities had a 50% lower drop rate and failure rate than students who attended lectures only. The combined drop and failure rate is normally 30%. Most students claimed to find the active learning projects entertaining and helpful. Even students who said that they do not ordinarily ask questions in lecture claimed to enjoy the small group interaction. They liked having time in class to think about their responses and work out answers with their peers. Social interaction appears to enhance the educational experience for the best as well as for the poorest non-honors students.

Students who attended cooperative-learning sessions had much better scores on questions concerning scientific concepts at the end of the semester than they did at the beginning. The grade averages of non-honors students on concept questions were 21% on the preliminary survey and 84% on the final exam. Honors students grade averages showed comparable improvement. Follow-up interviews verified that students attending cooperative-learning sessions did gain a good understanding of the scientific concepts presented in class. This was not the case for those students who attended lectures only. Many seem to have focused on algorithmic problem solving instead of conceptual understanding. They often failed to see the relevance of material presented and frequently complained when exam questions did not follow the format of homework problems exactly. The students who attended cooperative-learning sessions made no such complaints, indicating that they learned not to rely on memorized problem-solving algorithms but gained some ability to use the concepts underlying the questions. There was no difference between the honors and non-honors students in this regard.



Only a small number of students participated in our study in 2003, and the results described here are preliminary. However, they are similar to those obtained by other researchers (5,13). Cooperative-learning methods do help students to learn scientific concepts and problem solving skills. Also, our students claim that they help make their studies enjoyable, leaving them with a better impression of science.

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