Chemistry as General Education

Nivaldo J. Tro

Abstract

Science courses are common in most general education requirements. This paper addresses the role of chemistry courses in meeting these requirements. Chemistry professors have for many years questioned the appropriateness of the standard introductory chemistry course as general education. This has resulted in the growing popularity of specialized non-majors courses. I suggest that our current non-major courses cover too much consumer chemistry and ignore some of the big contributions of chemistry to human knowledge. Our major courses, while they prepare students for majoring in science, do not address these issues either. Consequently, chemistry courses are often an unpopular way to meet general education science requirements. Part of the reason for this dilemma is the lack of chemists who address the contributions of chemistry to human knowledge in general. I propose that faculty at liberal arts colleges engage this important task and that non-majors chemistry textbooks incorporate questions and issues that relate chemistry to a broader view of human knowledge. If these things happen, perhaps chemistry courses will become more popular as general education.

Introduction

Virtually all colleges and universities have one or more science courses as part of their graduation requirements. Chemistry departments normally offer courses that meet these requirements. These courses may be the same courses offered to science majors as part of their disciplinary training or they may be specialized courses designed for non-science majors. The non-science major courses are often viewed as watered-down versions of the disciplinary courses. The purpose of this paper is to address these courses and the role of chemistry in general education. What are the contributions of chemistry to greater human knowledge? What should we teach the non-science major?

These questions are not new. Papers in the *Journal of Chemical Education* dating back to 1927 (Baker 1128; Simons 461; Hopkins 418) address this issue. In 1941, an American Association for the Advancement of Science special committee reported the results of a survey on the opinions of science faculty on science for the purpose of general education (Taylor 10; Ashford 260). In that survey, only 31 percent of respondents indicated that the conventional introductory course was satisfactory for the non-science student. Several more recent articles make similar suggestions (Fernandez 624; Schultz 1001; Hohman 15788). Today, we have seen the emergence of specialized courses designed specifically for the non-science major. But do these courses, or the conventional courses, meet the aims of general education?

The Purpose of General Education

Before we can answer whether the chemistry courses we teach as part of general education actually meet the aims of general education, we must articulate those aims. This task is itself the subject of an entire volume, and there is much disagreement. However, we can outline the foundational aims that seem common, or at least should be common, to the majority of general education requirements.

Most general education requirements are related to liberal education or to the liberal arts, which in turn originate, at least etymologically, from the Latin term *artes liberales* (Kimball). An education in the *artes liberales* meant an education for the liberated or free person. It was an education that prepared a person to live a good life and to meet the responsibilities of conscientious citizenship. This meaning of education is missing from the lexicon of the modern college student. Most students today equate a college education with a good job. But of course that begs the question, why do they want a good job? The answer is, most probably, to make enough money to live a good life. Today's student has it backwards. For this reason, most students often see general education as something to get through and not as part of their core training, an unfortunate state of affairs.

The general education requirements at colleges and universities today are the descendents of the *artes liberales.* In this part of the curriculum, students are asked to take courses that prepare them – not for a specific job or vocation – but for citizenship and for life. Martha Nussbaum, in her book *Cultivating Humanity*, says that a liberal education is "a higher education that is the cultivation of the whole human being for the functions of citizenship and life generally" (Nussbaum). So the question we must ask as teachers of chemistry courses that are part of general education requirements is: what parts of chemistry are necessary for the cultivation of the whole human being and for the functions of citizenship?

The Problem of Overspecialization and The Role of Faculty at Liberal Arts Colleges

The question just posed is not one we are well equipped to answer. Do we ask this sort of question in graduate school? As undergraduates? Most of us get Ph.D.'s in highly specialized fields. Faculty at research universities are tenured and promoted – not for asking these kinds of broad questions – but for pushing the boundaries of their own specialized sub-fields of chemistry. In other words, our system is structured so that the work of most chemistry professors is for the benefit of the discipline itself. Given this structure, should we be surprised to find that the general public often misunderstands our discipline and us?

So, where can these sorts of questions be asked and answered? I propose that chemistry professors at liberal arts colleges address these questions as part of their professional work. Unfortunately, the research of most chemistry professors at liberal arts colleges is limited to work that is similar to the work of their colleagues at research universities. The main differences are that the research is normally done with undergraduate students and that it usually takes a slower pace. The teaching professor at a liberal arts college does not often have the time or resources available to the research university professor. Consequently, their research is valued, not so much for the contributions it makes to scientific knowledge, but for its role in preparing undergraduates for graduate school. While this is a worthy and important task, I question whether it should be the *only* task of the liberal arts chemistry professor. Do we not have room at our liberal arts colleges for some chemistry professors to ask and answer broader questions about our discipline and its relation to human knowledge in general? If not, then where are these questions to be addressed?

Chemistry as Liberal Education

Science has a long history as part of the liberal arts. In the late middle ages, the seven liberal arts were divided into two groups: the *trivium*, which included grammar, rhetoric, and logic; and the *quadrivium*, which included arithmetic, geometry, astronomy, and music. Science in general, and chemistry in particular, are ways of knowing about the world around us and knowing about ourselves, both central to the liberal arts (Shcwartz 13; Strong 562).

Understanding the world and how it works makes us richer and deeper persons. For example, according to popular legend, Arthur Eddington, upon hearing a friend comment about how beautifully the stars burned, said, "…and I know *how* they burn." For Eddington, understanding how stars emit light, and how they can do so for billions of years through nuclear fission, made the experience of viewing the stars a deeper and richer one. Similarly, John Henry Newman, in his 19th century book, *The Idea of a University*, says, "Hence Physical Science generally, in all its departments, as bringing before us the exuberant riches and resources, yet the orderly course, of the Universe, elevates and excites the student, and at first, I may say, almost takes away his breath…" (Newman).

This part of science – the part that enriches our lives through the understanding of our world – is lost on most people today. The average college student views science as utilitarian at best – it gives us DVD players and allows us to make better hairspray. Unfortunately, our non-science major chemistry courses have encouraged this perception through their emphasizing of technological applications as a way to generate interest. Many courses focus on consumer chemistry – the chemistry of lipstick, soap, and fertilizer. Many of the papers in this journal addressing non-science major courses also emphasize these sorts of applications (Ham 490; Barker 1278). But are these the great contributions of chemistry to human knowledge? Have we forgotten the big questions and settled for attempting to entertain our students with the small ones?

Professor Richard Feynman, in a lecture to first year physics students at the California Institute of Technology, said that the most important idea in all human knowledge is that *all things are made of atoms*. He went on to explain that if all other information were to vanish, this single idea would go farthest in allowing us to recreate what we know. As chemists, we may want to modify Feynman's assertion to include molecules. The idea that all things are made of atoms and molecules explains so much about our world and our experience of it. Atoms and molecules determine how matter behaves – if they were different, matter would be different. Water molecules, for example, determine how water behaves. Sugar molecules determine how sugar behaves, and the molecules that compose humans determine a great deal of how we behave. This is a fundamental contribution of chemistry to human knowledge. Do we emphasize this in our courses for non-majors?

Chemistry is by its nature, reductionistic, and reductionism is a word that should be in every college graduate's vocabulary. As chemists, we should clearly show our students why reductionism works so well in acquiring knowledge about the physical world. We should explain to them how the properties of substances are explained by the properties of their molecules. We should also raise questions about whether or not reductionism works to explain everything. It can certainly explain the behavior of water, and other substances, but can it explain the behavior of ants? Of humans? As chemists, we may not have all the resources to address these more complex questions, but we should at least ask them. They demonstrate that chemistry has something to say about the big questions that concern all humans.

The demise of Vitalism by the synthesis of urea in 1828 by Friedrich Wohler provides another opportunity to discuss the big questions related to chemistry. Before Wohler's discovery, scientists believed that humans and other living organisms contained a vital force, a non-physical force that allowed living organisms to synthesize organic compounds. When Wohler synthesized an organic compound in his laboratory, Vitalism was proved wrong. This discovery fundamentally changed how we view living things in general, and humans in particular.

As far as we can tell, the chemical reactions that occur in living organisms follow the laws of nature just like the chemical reactions occurring anywhere else. This discovery raises the sort of questions that every liberally educated person should ask during their college career. Does the fact that humans are composed of chemicals acting according to the laws of nature mean that human life is any less significant? Does it mean that the chemicals that compose us determine everything about us? Again, as chemists, we may feel ill equipped to address these questions. But if we fail to at least ask them, the role of chemistry and the breadth of our students' education are diminished.

Stanley Miller's experiments on the origin of life and subsequent work in chemical evolution represent another set of ideas that we should be teaching non-science majors. In 1953, Stanley Miller at the University of Chicago attempted to recreate primordial earth in the laboratory. He mixed several different compounds believed to be in the primordial atmosphere – methane (CH_4), ammonia (NH_3), water (H_2O) and hydrogen sulfide (H_2S) – in a sealed glass flask. He warmed the mixture for several days and simulated lightening with an electrical spark. When Miller opened the primordial soup, he found it to be rich in amino acids, the building blocks of proteins. Miller's experiment demonstrated that biologically important amino acids could be made under relatively simple primordial conditions. However, even though Miller's work was hailed as a key step in the origin of life, filling in the blanks between Miller's amino acids and a living cell has proven difficult.

The goal of origin-of-life research is to propose a number of steps – none of which is wildly improbable – that can explain how inanimate matter became living. Most current theories are based on the idea that at some point in the past a group of atoms formed certain molecules that, over time, developed the ability to reproduce themselves with increased efficiency from one generation to the next. These molecules became good at making copies of themselves – copies that in some cases could copy themselves better than their predecessors. Once this mechanism was in place, life – extremely good at copying itself in ways that leave room for improvement – could begin. The problem is that we have not figured out exactly what those molecules are or how it all happened. The field has no agreed-upon theory or paradigm. Every educated person should know this.

A discussion of quantum mechanics also presents opportunities for asking big questions with particular relevance to other disciplines such as philosophy and religion. We normally teach enough quantum mechanics in introductory or non-major chemistry courses so that students can write electron configurations and see pictures of orbitals. But we rarely focus on the impact of quantum mechanics on human knowledge. In quantum mechanical theory, for the first time in science history, scientists proposed that physical systems did not behave deterministically. The question of whether the universe and humans within that universe behave deterministically is age-old and of interest to thinkers in many different disciplines. Quantum mechanics tells us that, at least for the electron and other subatomic particles, the present *does not* determine the future. The universe seems to have at least some measure of freedom – an important piece of information for every liberally educated person to discover.

Science also raises a number of ethical issues and moral questions to which students should be exposed. For example, recent developments in therapeutic cloning (Cibelli 44) have raised questions of its morality. Most citizens, however, do not have sufficient scientific knowledge to understand these experiments or their implications. They hear the word "clone" and immediately think of an army of Hitler clones. In therapeutic cloning, scientists are not trying to make an army of Hitlers or even a single person. They are simply trying to reproduce human cells for the purposes of medical treatment. For example, if therapeutic cloning were successful, scientists could take a few cells from a person with a degenerative liver disease and coax them into growing new liver cells for treatment. Does the general public understand this? Is it our responsibility as chemistry professors to make sure that the students coming through our classes are exposed to these sorts of questions?

Lastly, every student taking a chemistry course as general education should be exposed to the myriad of environmental issues that our discipline addresses. These include global warming, ozone depletion, air pollution, water pollution, acid rain, and the use of energy resources (Dunnivant 1602). Understanding these issues, being able to intelligently read about them, and making choices with political consequences regarding them are important parts of conscientious citizenship in the 21st century. On this last point, our current non-science major courses are doing a better job than on previous points. However, many students can take an introductory chemistry course (designed for majors) to meet their general education requirement and miss these important topics.

Conclusion

Chemistry and science are essential to any general education requirements in the 21st century. However, our current non-major courses cover too much consumer chemistry and ignore some of the big contributions of chemistry to human knowledge. Our majors' courses, while they prepare students for majoring in science, do not address the issues that are important for liberal education. This problem is partly related to our educational system and to the highly specialized nature of chemical research. I propose that faculty at liberal arts colleges – who at least claim to have broader views of chemistry and its relation to other disciplines – include the big questions in chemistry in their professional work. Non-majors chemistry textbook authors must also begin to incorporate these questions into their books (Tro). If these things happen, perhaps students will seriously consider taking a chemistry course to meet there general education requirements in place of the more popular astronomy or geology courses.

Acknowledgements

I would like to thank the Provost at Westmont College, Shirley Mullen, for the freedom to think about these issues. I acknowledge the Westmont Liberal Arts Institute for support in the composition of this paper.

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