Vol. 29 | Núm. 1 | Págs. 65-76 | Marzo 2018
DOI: 10.22201/fq.18708404e.2018.1.63692

Investigación educativa

TEACHING (AND LEARNING) INTRODUCTORY CHEMISTRY COURSES IN CONTEXT: A 40-YEAR REFLECTION

Abstract

When instructors teach chemistry using real-world contexts, they weave connections between chemistry and the large public issues of our world. They also weave connections between chemistry and the smaller – but equally significant – personal issues in the lives of their students. Teaching and learning chemistry in real world contexts is not new; rather, it is a well-established practice backed by research on how people learn. What has one college chemistry instructor (and her students) learned over the past 40 years? The answer to this question is multi-dimensional, involving teaching philosophy, learning outcomes, changing contexts, changing content, and bringing the content and the contexts together. In answering this question, this paper employs air quality and plastics as examples of two real-world contexts that can engage students in learning chemistry through the "big questions" in our world today.

Keywords: college chemistry, introductory chemistry, general chemistry, context, real-world issues, interest in chemistry, relevance, plastics, polymers, air quality

ENSEÑANDO (Y APRENDIENDO) CURSOS DE QUÍMICA INTRODUCTORIA EN CONTEXTO: UNA REFLEXIÓN DE 40 AÑOS

Resumen

Cuando los instructores enseñan química usando contextos del mundo real, tejen conexiones entre la química y los grandes problemas públicos de nuestro mundo. También tejen conexiones entre la química y los problemas personales más pequeños, pero igualmente significativos, en la vida de sus alumnos. Enseñar y aprender química en contextos del mundo real no es nuevo; más bien, es una práctica bien establecida respaldada por investigaciones sobre cómo aprenden las personas. ¿Qué ha aprendido un instructor de química de la universidad (y sus alumnos) en los últimos 40 años? La respuesta a esta pregunta es multidimensional e involucra la enseñanza de la filosofía, los resultados del aprendizaje, los contextos cambiantes, el cambio de contenido y la unión del contenido y los contextos. Al responder a esta pregunta, este documento utiliza la calidad del aire y los plásticos como ejemplos de dos contextos del mundo real que pueden involucrar a los estudiantes en el aprendizaje de la química a través de las "grandes preguntas" en nuestro mundo de hoy.

Palabras clave: química universitaria, química introductoria, química general, problemas del mundo real, interés en la química, pertenencia, los plásticos, calidad del aire.

Autora: Cathy Middlecamp[1]

[1] University of Wisconsin-Madison, Madison, WI, United States. Mail to: chmiddle@wisc.edu

Vol. 29 | Núm. 1 | Págs. 65-76 | Marzo 2018
DOI: 10.22201/fq.18708404e.2018.1.63692

TEACHING (AND LEARNING) INTRODUCTORY CHEMISTRY COURSES IN CONTEXT: A 40-YEAR REFLECTION

Introduction

Context! The word derives from the Latin past participle of *contexere*, "to weave together." Teaching chemistry in context weaves chemistry into the very fabric of our world and its people. Conversely, teaching in context weaves the world and its people into the very fabric of our discipline, chemistry.

When instructors teach chemistry through real-world contexts, they weave connections between chemistry and the large public issues of our world. These issues connect to questions of importance, such as "How did plastic get in our oceans?" and "How is air quality related to public health?"

When instructors teach chemistry through real-world contexts, they also weave connections between chemistry and the smaller – but equally significant – personal issues in the lives of their students. These issues connect to questions of importance to their health and well-being, such as "What should I eat?" or "Is my water safe to drink?" or "Can I recycle my old cell phone?"

In the process of teaching in context, what can instructors learn? Embedded in this questions is the word *process*. A process is not a single step but rather a series of steps. A process does not demand a unique set of steps but rather can offer several pathways. And a process can be iterative, leading to improvement with the passage of time.

This paper is based on the premise that learning to teach in context is a process; that is, a series of steps. These steps, taken over time, lead to new understandings about context, about chemistry, about our chemistry students, and perhaps even about our world.

Others in chemical education community have documented the research that underlies teaching and learning in context (Fry and Wei, 2015; Mahaffy et al., 2017) and the need to engage students with the "big questions" (National Leadership Council for Liberal Education and America's Promise, 2007, p. 33). The practices used by teachers who teach in context also have been described (Meronia et al., 2015), as has been the concept of relevance in its multiple dimensions (Stuckey et al., 2013).

What is missing, however, are the personal reflections of those who have been teaching and learning in context for many years. This paper offers such a reflection. In the sections that follow, I will blend my insights from teaching chemistry in real-world contexts with the chemical content needed to understand the issues that we face in our world today.

An early step: Writing a Teaching Philosophy

Early in their professional journey, most college faculty members prepare a personal statement, sometimes called a teaching philosophy. This document is "an opportunity to formally represent personal ideas about teaching" (Eierman, 2008). At personal milestones such as promotion or tenure, instructors are likely to revise this teaching philosophy.

Over the past 40 years, I have revised my teaching philosophy many times, each time attempting to capture my understanding of teaching and learning. Although my teaching philosophy has changed, a common theme persists: *Teaching is an art*. Like any art, teaching requires practice and an investment of time over many years.

As a teacher, I have identified three tasks worthy of my time and steady practice: (1) knowing the chemical content, (2) knowing my students, and (3) and devising strategies to smoothly bring the content and students together. All three present challenges.

Knowing the content, task #1, concerns my knowledge of chemistry. Although chemical laws and principles remain largely the same, the field of chemistry is rapidly expanding. New fields have emerged in the past 40 years, including polymers, photovoltaics, air quality, nanotechnology, and genetic engineering. As an instructor, I am challenged both to learn the new content and to keep up with the recent developments.

Consider, for example, air pollutants, both indoors and out. In the last century, many countries, including the United States, Mexico, and Canada, have identified criteria pollutants and passed laws instituting air quality standards. Students now can access data on air pollutants via the internet, including daily air quality forecasts as shown in Figure 1 (U.S. Environmental Protection Agency, 2017). Unlike topics in general chemistry textbooks such as acids, net ionic equations, or Le Chatelier's Principle, the topic of air quality is rapidly expanding. Our understanding of the health effects of air pollutants is growing, the air quality standards are changing, our ability to detect air pollutants is increasing, and government agencies are communicating more information about air quality to their citizens.

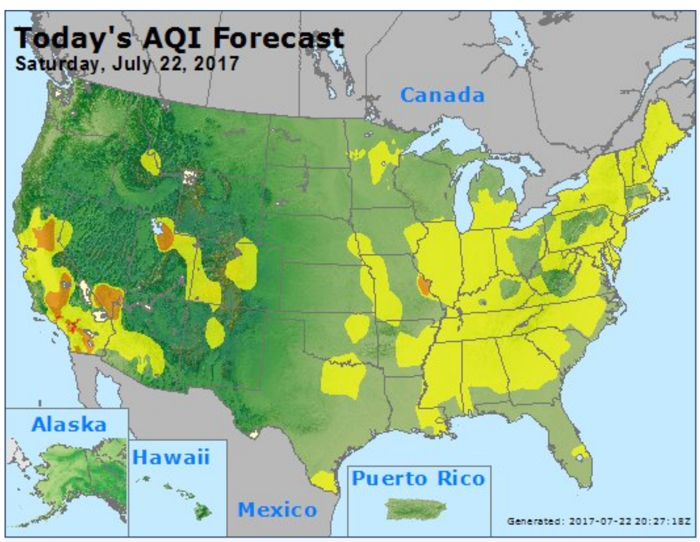

Figure 1. The forecast for ozone and fine particles in the United States and Puerto Rico, July 22, 2017.

Knowing the students, task #2, concerns my knowledge of people. As an instructor, I am challenged to keep current with the characteristics of each successive generation of students. Some personal characteristics are in rapid flux; for example, student capabilities with hand-held devices. In the United States, broad changes also are occurring in student demographics, including their age, employment status, marital status, and the

Vol. 29 | Núm. 1 | Págs. 65-76 | Marzo 2018
DOI: 10.22201/fq.18708404e.2018.1.63692

cultural groups from which they come (National Academies of Sciences, Engineering and Medicine, 2016). Other personal characteristics have remained remarkably stable. For example, I have observed that my students tend to:

(1) enter a chemistry course with apprehension about the difficulty of the course, sometimes anticipating that it will be taught in an unpleasant way (Vasquez y Manassero, 2008). In 1996, the U.S. National Science Foundation reported "such courses often were not geared to their individual ability level, were boring and difficult to follow because of the large lecture format, and were taught by instructors who seemed to care little about the subject matter or student learning" (Advisory Committee to the National Science Foundation, 1996 p. iii).
(2) enroll because the course is a requirement; in essence, a gateway to their chosen profession. The stakes are high. If students fail to do well, they may fail to enter a profession such as engineering, medicine, or nursing.

Devising strategies to smoothly bring the content and the students together, task #3, is the topic of this paper. In my experience, setting chemical content in a real-world context offers almost limitless opportunities to engage students in learning chemistry. For the purposes of illustration, this paper makes use of two real-world contexts: air quality (this section and next) and plastics (the final two sections).

In making the case for teaching chemistry in context, I repeatedly encounter one obstacle in the mind of instructors: Time to teach content. Teaching in context is perceived as taking time from content, resulting in less rigor. Does introducing a context "water down" a chemistry course? The next section provides speaks to this question – and more.

Another step: Writing learning objectives

Forty years ago, faculty members at my university were not required to submit learning objectives as part of a syllabus or a new course proposal. Times have changed! Learning objectives now are woven into the fabric of instruction, appearing in syllabi, textbooks, and laboratory manuals. In addition to content, learning outcomes now address civic knowledge. For example, the American Association of Colleges and Universities recommends "an active commitment to personal and social responsibility; and the demonstrated ability to apply learning to complex problems and challenges" (National Leadership Council for Liberal Education and America's Promise, 2007, p. 3).

Learning objectives usually are constructed at the course level. For example, for many years I taught a context-rich general chemistry course for non-science majors using the textbook Chemistry in Context, a project of the American Chemical Society (Middlecamp et al., 2015). Here are some of the learning objectives on air quality for "The Air You Breathe," the opening chapter:

- Name the primary constituents of our atmosphere. Provide chemical formulas and describe their chemical behavior.
- Name the 5 criteria air pollutants, as specified by the United States Environmental Protection Agency. For each, list two natural sources and two human-related sources.

- Compare and contrast how these 5 air pollutants are produced.
- Interpret local air quality data, including why standards are needed separately for each air pollutant.

The first two objectives are low-level; that is, they require memorizing chemical information. In contrast, the third is higher level: tropospheric ozone formation requires an understanding of the formation of nitrogen monoxide in motor vehicle engines (or from coal- or natural gas-fired electric utility plants), its subsequent oxidation in air to nitrogen dioxide, the role of sunlight in breaking chemical bonds in nitrogen dioxide, and the rapid formation of ozone from molecular oxygen and oxygen atoms. In contrast, carbon monoxide is a result of incomplete combustion. The fourth is higher level as well, requiring knowledge of how each air pollutant impacts human.

At the course level, I also have written three deceptively simply overarching learning goals for my first-year non-major chemistry students. These are described in the next section.

Another step: Writing overarching course goals

What really matters in a course? Over the years, I have come to settle on three items for all of my students: science majors and non-majors alike. I want my students to:

1. learn chemistry,
2. enjoy learning chemistry, so after my course, they
3. want to keep learning chemistry.

Of course learn chemistry! But as an instructor, I came to realize that my "covering" chemical content was not equivalent to students learning it. Furthermore, I learned that covering too much content could quickly kill a student's love of learning.

What conditions promote student learning? I have observed that people - including students – are more likely to invest time learning something when it catches their interest, satisfies their curiosity, and/or connects to something they care about. Recent research backs up my observations. A student's motivation to learn is complex, dependent on no single factor but rather on several interlocking factors (Ambrose et al., 2010). "Students are typically more motivated to engage with material that interests them or has relevance for important aspects of their lives. … Assign problems and tasks that allow students to vividly and concretely see the relevance and value of otherwise abstract concepts and theories" (Ambrose et al., 2010, p. 83).

"Everyone has understanding, resources, and interests on which to build" (National Research Council, (2000), p. 138). The students who have enrolled in my courses did not at first always realize how well chemistry builds on their interests. For example, consider ozone and its formation as an air pollutant at ground-level. Tropospheric ozone pollution is relevant to those who live in urban areas or who may be employed there in the future. Ozone also connects to plant damage, including crops. Students may not know how ozone affects their lungs (and eyes), and they may not know which people are the most

Vol. 29 | Núm. 1 | Págs. 65-76 | Marzo 2018
DOI: 10.22201/fq.18708404e.2018.1.63692

sensitive to high levels. Similarly, they may not know when and how to exercise if ozone levels are high. As they learn more about air pollutants, students may become hooked on daily air quality maps (Figure 1), checking these much as they check daily weather maps (U.S. Environmental Protection Agency).

Learning about ozone opens the door to learning chemistry. As students meet the three major players on the atmospheric stage, O, O_2 and O_3, they also become interested in electronic configurations and bonding. A step in tropospheric ozone formation is the splitting of NO_2 by sunlight to release O atoms, a player in ozone formation. Thus, air pollution also may spark an interest in sunlight and the electromagnetic spectrum.

A real-world *context* such as air pollution thus can drive the *content* that students need to learn, providing a rationale for instructors to delve into the chemistry principles involved. *Context* and *content* do not compete with each other; rather, they are two sides of the teaching and learning coin (Figure 2). Knowing who or what is important; knowing the bigger picture is equally important. Rather than simply "covering content," teachers can uncover it.

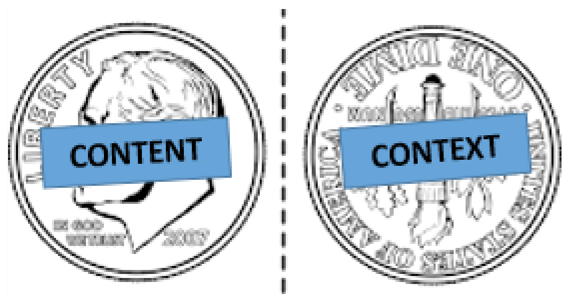

Figure 2. Content and context are two sides of the teaching and learning coin.

Item #2, "enjoy learning chemistry," has held its place for many years on my list of overarching goals. Why? Some argue that it doesn't matter whether students find enjoyment; rather, the important thing is for them to learn the material so they can use it in a later course. This strikes me as ill-formed logic, overly placing the emphasis on future study. First, many students never take another chemistry course. Second, the medical oath "First, do no harm" applies to teachers as well as to doctors. If I kill a student's desire to learn, I have failed as a teacher.

Item #3 on my list of overarching objectives commands my attention today. I seek content that has the power to engage students in learning chemistry over a lifetime. Hence my rationale for employing real-world contexts –global and local – through which to teach chemistry to my future citizens, future parents, and future professionals.

To this end, I spent twenty years as an author for Chemistry in Context, a project of the American Chemical Society. As of 2017, nine editions of this college textbook for non-science majors that "applies chemistry to society" have been published. Real-world contexts include air quality, ozone depletion, climate change, energy, water, plastics, food, batteries, and genetic engineering. As the editor-in-chief of the eighth edition, I wrote in the preface:

> **"Context!** Are you aware that using a real-world context to engage people is a high impact practice backed by the research on how people learn? Chemistry in Context offers real-world contexts through which to engage learners on multiple levels: personal, societal, and global. Given the rapidly changing nature of these contexts, Chemistry in Context also offers teachers the opportunity to become learners right along with their students."

Educación Química
Vol. 29 | Núm. 1 | Págs. 65-76 | Marzo 2018
DOI: 10.22201/fq.18708404e.2018.1.63692

The next section describes plastics as a real-world context, demonstrating how I became a learner right along with my students.

A later step: Teaching in the context of plastics

In the late 1970s, my early years as a chemistry instructor, polymers had a place in the curriculum of general chemistry courses. When I first taught the topic, I explained that a polymer was a big molecule made from little molecules called monomers. We examined the monomers of addition polymers and condensation polymers. We compared natural polymers (proteins, starch, cellulose) with human-made polymers (polyethylene, polystyrene, polypropylene). I mentioned recycling as a useful bit of real-world chemistry. After this, I called it a day and moved to another topic.

Starting in the 1990s, I changed my approach. Rather than starting with what a polymer was, I started with a larger context. Using this context, I developed a need to know more chemistry and then provided the necessary content. This approach was clearly articulated in the 2000s by a U.S. national curriculum reform project, SENCER, Science Engagement for New Civic Responsibilities and Engagements: "SENCER courses and programs strengthen student learning and interest in science, technology, engineering, and mathematics by connecting course topics to issues of critical local, national, and global importance" (SENCER). What did I learn about teaching and learning in context?

Contexts have multiple points of entry: The topic of "plastics in our world" offers an instructor many points of entry:

- Personal. Plastics are part of our daily life. For example, consider a running shoe, a bicycle, a cell phone, or refillable water bottle (Macrogalleria).
- A controversy. Plastics are in the news! The use of DEHP and other phthalates in infant toys and medical bags and tubing was in the spotlight in the 2000s. More recently, it has been BPA in water bottles (Ritter, 2011).
- Global. Plastic debris is accumulating in huge "garbage patches" in the ocean. Photographs of animals eating plastic (Figure 3) or being ensnared in plastic are a launch point (National Oceanic and Atmospheric Administration).

Figure 3. According to the North Carolina Aquarium, all sea turtles are listed as endangered or threatened. Plastics in the ocean is one contributing factor (North Carolina Aquarium).

The points of entry are likely to change with the passage of time: As strong, flexible, durable and/or waterproof, plastics are incredibly useful materials. However, in recent years we have learned just how durable plastics really are. The "immense eternal footprint

Vol. 29 | Núm. 1 | Págs. 65-76 | Marzo 2018
DOI: 10.22201/fq.18708404e.2018.1.63692

of plastic" is now squarely in the public eye (Schlossberg, 2017). As such, it presents an opportunity to engage students in learning about plastics:

"Researchers collected data on the fate of all plastic since the material was initially mass-produced in the 1950s. By 2015, humankind had manufactured 8.3 billion metric tons of the stuff and generated 6.3 billion metric tons of plastic waste. Of this, 9% was recycled and 12% incinerated. The vast majority, 79%, was tossed, the team reports today in *Science Advances.* If these trends continue, by 2050 we'll have produced 26 billion metric tons of plastic waste, almost half of which will be dumped in landfills and the environment. Because plastic doesn't degrade easily, there will be zillions of tons of the material on our planet by the end of the millennium" (Guglielmi, 2017).

The durability of plastic, once viewed as an asset, today has unintended consequences in the oceans. As another recent article points out so well:

"The problem of plastic waste has arisen because of lack of systems thinking — a failure to look beyond the immediate utility of a product during its active life. In all areas of product manufacture, systems thinking requires that recycling considerations should be included from the outset, taking an overview of the beginning-to-end life of a product, including its life as waste and as recyclable material" (Matlin, et al., 2016, p. 395).

The life cycle of plastics currently is my point of entry, starting with the PET bottles (and their caps) that litter our landscapes and eventually make their way to the oceans.

No matter which point of entry I selected, I needed to learn more content: Teaching in a context such as "human health and air pollution" or "personal use of plastics" presented me with two instructional challenges. First, these topics required that I learn new content. Second, once learned, this content needed to be updated regularly.

For example, when I first started teaching with "Plastics & You," I need to learn new content. I did not know, for example, the extent to which HDPE was employed to package items such as shampoo, detergent, glue, vinegar, and ammonia (but not oily substances). Similarly, I had to learn that not only was PETE widely used for clear beverage bottles but also it could be spun into a fiber for fleece clothing. Over time, I watched how the use of PVC changed. While once widely used, vinyl packaging now largely has been replaced by other polymers with similar durability and high luster. I also saw new issues emerge, such as plastics in the ocean. Keeping current with this topic requires that I continually monitor the ongoing marine debris research (National Oceanic and Atmospheric Administration). So much to learn!

No matter which point of entry I selected, I needed new skills in the classroom: Pedagogy, how we engage students in learning, is as important as content, what we teach. Once again, I had much to learn. For example, bringing controversies into the classroom required new skills, including leading discussions, coaching students to balance speaking and listening, and at becoming better at recognizing when to reveal my own opinions on an issue. I also needed to learn more about the nature of controversies, for example; not only are some issues controversial, but also a controversy might exist over whether the issue was controversial or not. Teaching chemistry using climate change is an excellent case in point (Flener-Lovitt, 2014; Mahaffy et al., 2017).

Real-world topics open the possibility of research experiences: Today, undergraduate research is recognized as a high-impact practice (Lopatto, 2010). In two recent reports from the National Academies of Sciences, Engineering and Medicine, science faculty members describe the impacts of research on undergraduate student learning. (National

Vol. 29 | Núm. 1 | Págs. 65-76 | Marzo 2018
DOI: 10.22201/fq.18708404e.2018.1.63692

Academies of Sciences, Engineering, and Medicine, 2015 and 2017).

Starting in 2013, I began teaching an introductory level environmental science course that enrolled just over 100 students. As my students learned about plastics, they also researched the contents of the trash on campus. After learning proper safety protocols, students donned two pairs of gloves (outer Kevlar gloves resistant to cuts and inner nitrile gloves as a liquid barrier), Tyvek suits, eye protection, and got to work. During each of five successive spring semesters, they audited approximately 400 pounds of trash from a campus residence hall. The students were assigned the task of separating the trash that could be recycled, weighing it, and then re-bagging the plastic for recycling. In order to do this, students had to learn to identify different types of plastics and know which ones were recyclable in our local community. The data they collected provided useful information to campus officials about the residence hall waste streams (National Academies of Sciences, Engineering, and Medicine, 2015 p. 32-33). The next section tells more about teaching and learning in the context of a college campus.

A recent step: My university campus as a context

Just prior to 2000, the phrase "campus as a living laboratory" arose in connection with engaging students in learning about sustainability (Cohen, T. and Lovell, B.). The "living laboratory" approach is motivated by a growing understanding that "The campus is the most readily available laboratory for hands-on projects, and acts as a shadow curriculum for the students to apply to the campus what they learn in the classroom" (McMillan and Dyball, 2009)

Starting in 2013, I used my campus as a "living laboratory" to engage students in hands-on projects to learn environmental stewardship – and chemistry – in purposeful and practical ways (Lindstrom, T. and Middlecamp, C., 2017). For example, students estimated the carbon footprint of meals served on campus (Bryan and Middlecamp, 2017a). An outcome of this activity was a collaboration with a test kitchen on campus, leading to the creation of a new lower carbon footprint vegetarian entrée that now is served on campus (Bryan and Middlecamp, 2017b). Described in the previous section, conducting research on residence hall trash is another example of using the campus as a "living laboratory."

Concluding Thoughts

Early in my career, I taught chemistry majors. Soon after, I switched to teaching chemistry to science majors, and then later to non-science majors. Most recently, I have been teaching environmental science and environmental studies to both majors and non-majors. These groups of students are not as different as might appear at first glance. Although they differ in their mathematical sophistication and previous knowledge of chemistry, all shared a common characteristic: an interest in how chemistry applies to local, regional and global issues of consequence. In addition, they shared a willingness to delve into a challenging problem for which the answers were not in the back of the book. As a teacher, I shared this willingness.

Learning to teach using rich, real-world contexts is not just a task to accomplish; rather, it is a process in which an instructor must reflect and revise each step of the

Vol. 29 | Núm. 1 | Págs. 65-76 | Marzo 2018
DOI: 10.22201/fq.18708404e.2018.1.63692

way. This process involves rethinking the content, being knowledgeable about students, and smoothly bringing the students and the content together. This process also requires setting and revising learning objectives and overarching course goals. Finally, as the years roll by, it requires continuously learning new content and new teaching skills.

Teaching and learning chemistry in the context of real-world issues is a high-impact practice supported by the research on how people learn. As a result, context-rich teaching now is finding a rightful place for students at all levels. High school teachers have stated the case for context-rich science teaching as well: "K–16 science and engineering instruction be provided within the context of personal and societal issues" (National Science Teachers Association).

Teaching and learning chemistry in the context of real-world issues is both timely and urgent. A context-rich approach not only improves student learning but also better prepares students to become well-informed citizens. By any standard, this represents a win for our students, for our discipline, and for the wider communities in which we live.

Acknowledgment

The author gratefully acknowledges many students and colleagues – locally, nationally, and internationally – who have been her teachers over the years.

References

Advisory Committee to the National Science Foundation, (1996). Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology, National Science Foundation, United States, NSF 98-128, p. iii.

Ambrose, S. A., Bridges, M. W., DiPietro, M, Lovett, M. C., and Norman, M. K. (2010). *How Learning Works: Seven Research-Based Principles for Smart Teaching,* San Francisco, CA, United States: Jossey-Bass, Consulted on July 23, 2017 in URL http://www.wiley.com/WileyCDA/WileyTitle/productCd-0470484101.html

Bryan, T. W. and Middlecamp, C. H., (2017a). Learning through Eating: Bringing Campus Dining Operations into an Environmental Science Course, *Sustainability: The Journal of Record*, *10*(1), 30-38.

Bryan, T. W. and Middlecamp, C. H., (2017b). The Story of Crispy Golden Tofu, *Sustainability: The Journal of Record*, *10*(4),1-7.

Cohen, T. and Lovell, B. *The Campus as a Living Laboratory: Using the Built Environment to Revitalize College Education*. American Association of Community Colleges Sustainability Education and Economic Development Center; U.S. Green Building Council Center for Green Schools. Consulted on July 23, 2017 in URL http://www.theseedcenter.org/getattachment/Resources/SEED-Resources/SEED-Toolkits/Campus-as-a-Living-Lab/Campus-as-a-Living-Lab.pdf

Eierman, R. J. (2008). The teaching philosophy statement: Purposes and organizational structure, *Journal of Chemical Education, 83*(3), 336-339.

Flener-Lovitt, C. (2014). Using the Socioscientific Context of Climate Change to Teach Chemical Content and the Nature of Science, *Journal of Chemical Education*, *91*(6), 1587−1593.

Fry, C. and Wei, C. (2015). Sustainability matters for undergraduate teaching and learning. *Journal on Excellence in College Teaching, 26*(3), 5-24.

Vol. 29 | Núm. 1 | Págs. 65-76 | Marzo 2018
DOI: 10.22201/fq.18708404e.2018.1.63692

Guglielmi, G. (2017). In the next 30 years, we'll make four times more plastic waste than we ever have, Science, American Association for the Advancement of Science, Jul. 19, 2017. Consulted on July 23, 2017 in URL http://www.sciencemag.org/news/2017/07/next-30-years-we-ll-make-four-times-more-plastic-waste-we-ever-have.

Lindstrom, T. and Middlecamp, C. (2017). Campus as a Living Laboratory for Sustainability: The Chemistry Connection. *Journal of Chemical Education, 94*(8), 1036-1042.

Lopatto, D. (2010). Undergraduate Research as a High-Impact Student Experience in American Association of Colleges and Universities, Peer Review *12*(2). Consulted on July 23, 2017 in URL https://www.aacu.org/publications-research/periodicals/undergraduate-research-high-impact-student-experience.

Macrogalleria, Polymers are Everywhere, Consulted on July 23, 2017 in URL http://pslc.ws/macrog/level1.htm

Mahaffy, P. G., Holme, T. A., Martin-Visscher, L., Martin, B. E., Versprille, A. Kirchhoff, M., and McKenzie, L. (2017). Beyond "Inert" Ideas to Teaching General Chemistry from Rich Contexts: Visualizing the Chemistry of Climate Change (VC3), *Journal of Chemical Education, 94*, 1027-1035.

Matlin, S. A., Mehta, G., Hopf H., and Krief, A. (2016). One-world chemistry and systems thinking, *Nature Chemistry,* 8, 393–398.

Meronia, G., Copelloa, M. I., y Paredesa, J. (2015). Enseñar química en contexto. Una dimensión de la innovación didáctica en educación secundaria, *Educación Química*, *26*(4), 275-280.

McMillin, J. and Dyball, R. (2009). Developing a Whole-of-University Approach to Educating for Sustainability, *Journal of Education for Sustainable Development, 3*(1), 55−64.

Middlecamp, C. H., Mury, M., Anderson, K., Bentley, A., Cann, M., Ellis, J. and Purvis-Roberts, K. (2015). Chemistry in Context, 8th edition, Dubuque, IA, United States: McGraw–Hill.

Middlecamp, C. H., (2016). "Teaching and Learning About Sustainability: The View from CHED," in *Teaching and Learning About Sustainability*; Levy, I. and Middlecamp, C. H., Eds; ACS Symposium Series 1205; Washington, DC: The American Chemical Society.

National Academies of Sciences, Engineering, and Medicine, (2015). *Integrating Discovery-Based Research into the Undergraduate Curriculum: Report of a Convocation*. Washington, DC, United States: The National Academies Press. Consulted on July 23, 2017 in URL https://doi.org/10.17226/21851.

National Academies of Sciences, Engineering, and Medicine, (2016). *Barriers and Opportunities for 2-Year and 4-Year STEM Degrees: Systemic Change to Support Students' Diverse Pathways*. Washington, DC: The National Academies Press. Consulted on July 23, 2017 in URL https://doi.org/10.17226/21739.

National Academies of Sciences, Engineering, and Medicine, (2017). *Undergraduate Research Experiences for STEM Students: Successes, Challenges, and Opportunities*. Washington, DC: The National Academies Press. Consulted on July 23, 2017 in URL https://doi.org/10.17226/24622.

National Leadership Council for Liberal Education and America's Promise, (2007). *College Learning for the New Global Century*, Washington, DC, United States: American Association of Colleges & Universities.

Vol. 29 | Núm. 1 | Págs. 65-76 | Marzo 2018
DOI: 10.22201/fq.18708404e.2018.1.63692

National Oceanic and Atmospheric Administration, Marine Debris Program, Consulted on July 23, 2017 in URL https://marinedebris.noaa.gov/.

National Research Council, (2000). *How People Learn: Brain, Mind, Experience, and School: Expanded Edition*. Washington, DC, United States: The National Academies Press. Consulted on July 23, 2017 in URL https://doi.org/10.17226/9853.

National Science Teachers Association, Teaching Science and Technology in the Context of Societal and Personal Issues, Consulted on July 23, 2017 in URL http://www.nsta.org/about/positions/societalpersonalissues.aspx

North Carolina Aquarium, Just say No to Plastic, consulted on July 22, 2017 in URL http://seaturtleexploration.com/just-say-no-to-plastic/

Ritter, S. K. (2011). Debating BPA's Toxicity*, Chemical and Engineering News, 89*(23) *14-19.*

Schlossberg, T. (2017). The Immense, Eternal Footprint Humanity Leaves on Earth: Plastics, New York Times, July 19, 2017.

Science Education for New Civic Engagements, Our Mission, consulted on July 22, 2017 in URL http://sencer.net/our-mission/.

Stuckey, M., Hofstein, A., Mamlok-Naaman, R., and Eilks, I. (2013), The meaning of 'relevance' in science education and its implications for the science curriculum, *Studies in Science Education*, *49*(1), 1–34.

U.S. Environmental Protection Agency, AirNow, Today's Air Quality Forecast, consulted on July 22, 2017 in URL https://www.airnow.gov/.

Vázquez, A. y Manassero, M.A. (2008). La química y el contexto de los estudiantes:el género y la primera elección de ciencias, *Educación Química*, Octubre, 295-302