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Challenges in Environmental Education: Curriculum and Students
by Ashok Kumar and Susan Wierman

Quality environmental education is critical to excellence in environmental professions, both for students and professionals. This issue of EM focuses on two current challenges educators face in delivering environmental education: the ongoing need for curriculum updates, and how to educate the new generation of students.

Features

Four Evolutions in Environmental Engineering: Effects on Curricula
by Melanie Sattler

An Introduction to Python Programming for Environmental Professionals
by David Lampert

Are We Ready to Teach Generation Z?
by Zaher Hashisho and Alireza Haghighat Mamaghani

Columns

EPA Research Highlights: STEM Outreach at EPA Provides Opportunities for Students and Teachers
by Melissa Anley-Mills

An overview of EPA’s environmental education and Science, Technology, Engineering, and Mathematics (STEM) resources and activities.

Etcetera: The Supreme Court Revisits and Revises ‘Auer Deference’ with Implications for Environmental Law
by Anthony B. Cavender, Ashleigh Acevedo, and Rebecca Lee

The U.S. Supreme Court’s decision in Kisor v. Wilkie will likely affect the judicial review of many federal regulatory actions, including environmental matters governed by the U.S. Clean Air Act, Clean Water Act, and Resource Conservation and Recovery Act (RCRA), which could have significant consequences on the regulated community.

Departments

Message from the President:
Education 360°
by Kim Marcus

Back In Time: A&WMA’s Annual Critical Review Turns 50
This year, we celebrate 50 years of A&WMA’s Annual Critical Review.
This month’s *EM focuses on education*, which has always been an important topic for me. I have been, and am currently, associated with several school boards and as a lecturer, from pre-K through to university level. Through these experiences, I have learned three core truths about education: (1) a good education can greatly enhance a person’s life, (2) you can always learn more, and (3) everyone has something to teach.

When I hear statements such as the fact that more or less 90% of the data created in human existence has been generated in the last two years and that the pace is only accelerating, I am reminded of the importance of A&WMA members’ role in creating, digesting, assimilating, and disseminating accurate and factual data and the implications of that information. One of the most important aspects and benefits of being a neutral forum is that we allow for varied and different opinions related to the interpretation of data, and provide avenues for it to be elucidated, discussed, and debated. Our forums allow for listening, learning, sticking with or changing our opinions, and agreeing to agree or disagree. Listening is a skill that is difficult to master, but it’s clear that our members are good at it. Our Association’s emphasis is about sharing, teaching, learning, and connecting. We are all becoming better educated, even as we are all educating one another.

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Quality environmental education is critical to excellence in environmental professions, both for students and professionals. This issue of EM focuses on two current challenges educators face in delivering environmental education: the ongoing need for curriculum updates, and how to educate the new generation of students.
One of the challenges faced by environmental educators is keeping course content current and relevant to industry and societal needs. The first article by Melanie Sattler focuses on trends observed in the 2019 report *Environmental Engineering for the 21st Century: Addressing Grand Challenges* published by the National Academies. Trends include:

1. Prevention preferred over treatment;
2. Climate change – a cross-cutting issue;
3. Criticality of addressing connections/nexus among problems; and

Sattler points out needed changes to current course work in order to meet these grand challenges.

The second article by David Lampert identifies new computer skills needed to handle the enormous amount of data generated daily by environmental sensors. Lampert explains and recommends training on the use of the Python Programming Language, which is now widely used in data science.

The third article in this group focuses on teaching and learning strategies for Generation Z—the generational identifier for those students just entering higher education. Zaher Hashisho and Alireza Haghighat Mamaghani describe the characteristics of Generation Z (preferring technology and digital tools, pragmatic, individualistic, independent, cautious, having a short attention span, and desiring immediacy and convenience), and the authors explain changes in teaching styles that can help educators relate to these characteristics.

To quote a useful book on the science of successful learning, “The responsibility for learning rests with every individual, whereas the responsibility for education (and training, too) rests with the institutions of society.” *1* Research in cognitive science indicates that intermittent training involving practice and reflection on the relevance of key information facilitates learning and retaining needed knowledge. The ideas in these three articles can help educators present relevant training for future environmental professionals, and they also point the way for environmental program managers to encourage lifelong education for continued professional improvement.

Dr. Ashok Kumar is a distinguished university professor and chair of the Department of Civil and Environmental Engineering at The University of Toledo, OH. Susan S.G. Wierman is the past Executive Director of the Mid-Atlantic Regional Air Management Association, and currently a lecturer in the Engineering for Professionals Program at Johns Hopkins University, Baltimore, MD.

Reference

This article examines four recent developments in the field of environmental engineering, and their effects on higher education curricula.
With the passage of major environmental legislation in the early 1970s, the field of environmental engineering grew rapidly. Over the past half-century, environmental engineers have succeeded in improving the quality of life in the United States and other countries by providing water and wastewater treatment infrastructure, sanitary landfills, and air pollution controls. In the early 1970s, the global population of 3.4 billion was less than half the present-day population of 7.7 billion, and many countries were not yet developing, meaning that energy and material resources were less strained. Mega cities—and their accompanying challenges in terms of pollution—were few. Today's world looks quite different. To meet the challenges of the present day, the field of environmental engineering is of necessity evolving. To ensure that our students are better prepared to meet current challenges, the environmental engineering curriculum must evolve as well.

Released in 2019 by the National Academies, Environmental Engineering for the 21st Century: Addressing Grand Challenges discusses some of the ways in which the field of environmental engineering is changing. Based on the National Academies’ report, as well as the author’s own experience, this article will discuss four selected evolutions in the field of environmental engineering, and their effects on curricula:

1. Prevention preferred over treatment;
2. Climate change—a cross-cutting issue;
3. Criticality of addressing connections/nexus among problems; and

The discussion cannot be comprehensive due to space limitations; other trends, such as inclusion of sustainability, the need for interdisciplinary learning and teaching, and study abroad, or Accreditation Board on Engineering and Technology (ABET) requirements, are not included.

Prevention Preferred Over Treatment
The familiar saying “an ounce of prevention is worth a pound of cure” applies not only in the medical field, but also in environmental engineering. Preventing pollution from being formed in the first place is typically cheaper than cleaning it up after it has formed. For example, since 1975, 3M’s Pollution Prevention Pays (3P) program has prevented more than 2.1 million tons of volatile organic compounds from being released and saved nearly US$2 billion. Preventing pollution from forming in the first place is also more energy efficient: pollution is a form of disorder, and cleaning it up requires working against the second law of thermodynamics (processes tend toward disorder, without an external energy input).

Environmental engineering historically has been treatment-process focused, or end-of-pipe focused: once pollution is created, environmental engineers use principles of chemistry, biology, and physics to clean it up. Air pollution control engineers, for example, design devices that can be used to remove pollution from coal-fired power plant exhaust before it is discharged into the atmosphere. A more efficient approach, however, is to ask the question: how can we avoid generating the air pollution in the first place? This question...
leads to consideration and design of sustainable power systems, such as biogas from waste, solar power, and wind power.

In terms of curricula, faculty members can consider supplementing units/courses focused on traditional end-of-pipe treatment with those focused on pollution prevention. For example, a new course on renewable energy system design might be offered in addition to a traditional course on air pollution control system design, or a unit on solid waste minimization could complement a traditional unit on landfill design.

Climate Change
The issue of climate change affects most traditional areas of environmental work. For example, higher temperatures will increase ground-level ozone formation. Changes in precipitation patterns will impact water supplies. The need to reduce emissions of the greenhouse gas methane will engender changes in landfill design and operation.

Since climate change is a cross-cutting issue, faculty members teaching any environmental engineering course can discuss climate change effects and prevention strategies related to the main topic of their course. Faculty can also incorporate climate change into problems and design projects. For example, a main strategy to reduce greenhouse gas emissions is reducing fossil fuel consumption by increasing energy efficiency. Thus, in a homework problem in a water/wastewater treatment design course, which requires students to choose among wastewater treatment processes, energy consumption can be included as a criterion. As another example, if students are doing photochemical modeling of ozone, a problem can require them to compare ozone formation at current temperatures and future warmer temperatures.

Interrelated Problems
Environmental engineers increasingly appreciate that major environmental challenges are often interrelated. The National Science Foundation, for example, has for the past several years funded research related to the food–water–energy nexus. This nexus is important because 70% of global water withdrawals are for agriculture, and food production generates 22% of global greenhouse gas emissions (including landfilling of food waste). Environmental engineering educators can better prepare the engineers of tomorrow by emphasizing fundamental concepts that apply across media, particularly life cycle assessment (LCA), which estimates environmental impacts on all media of a product or process during its entire life cycle (see Figure 1). Other fundamental concepts, although more traditional, include mass and energy balances, transport processes (advection, dispersion, diffusion), and control processes (adsorption, organics oxidation, etc.). These concepts can be integrated into media-specific courses, such as wastewater treatment and air pollution control. Alternatively, they can be taught in a series of general courses (e.g., Sustainable Engineering, Transport Processes, and Control Processes), which use applications in specific media as examples.

Global Perspective
In most areas of environmental engineering, the most critical challenges today lie in developing countries. For example, according to the World Health Organization (WHO), 98% of cities in low- and middle-income countries with more than 100,000 inhabitants do not meet WHO air quality guidelines. In high-income countries, the percentage decreases to 56%. As shown in Table 1, the 10 cities globally with the highest ambient PM$_{2.5}$ levels are all in all in developing countries.

To bring a global perspective to their courses, faculty members can add international information into lectures, such as the table above. They can also consider assigning projects with a global perspective. For example, the project in my “Fundamentals of Air Pollution” course typically involves estimating emissions, conducting dispersion modeling, and recommending control technologies for an international source. Over the past several years, my students have evaluated air pollutants from a number of sources in Thailand: a municipal solid waste incinerator, waste gasification plant, print shop, and sesame roasting plant.

In addition, faculty members might consider adding entire courses with an international focus, such as the “Site Remediation in Developing Countries” elective course recently introduced at the University of Texas at Arlington. This course focuses on the application of scientific and engineering principles and practices to the remediation of contaminated water, air and land in developing countries. Students synthesize a variety of topics ranging from science and engineering to social issues such as environmental justice and international relations to solve environmental problems.
Table 1. Cities with the highest ambient PM$_{2.5}$ levels.$^4$

<table>
<thead>
<tr>
<th>Rank</th>
<th>City</th>
<th>Annual Mean (µg/m$^3$)</th>
<th>Primary Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Zabol, Iran</td>
<td>217</td>
<td>Wetlands drying out</td>
</tr>
<tr>
<td>2</td>
<td>Gwalior, India</td>
<td>176</td>
<td>Coal combustion, cars</td>
</tr>
<tr>
<td>3</td>
<td>Allahabad, India</td>
<td>170</td>
<td>Drying of the Ganges river</td>
</tr>
<tr>
<td>4</td>
<td>Riyadh, Saudi Arabia</td>
<td>156</td>
<td>Industry</td>
</tr>
<tr>
<td>5</td>
<td>Al Jubail, Saudi Arabia</td>
<td>152</td>
<td>Industry</td>
</tr>
<tr>
<td>6</td>
<td>Patna, India</td>
<td>149</td>
<td>Transportation, power, industry</td>
</tr>
<tr>
<td>7</td>
<td>Raipur, India</td>
<td>144</td>
<td>Coal combustion; steel &amp; aluminum production</td>
</tr>
<tr>
<td>8</td>
<td>Bamenda, Cameroon</td>
<td>132</td>
<td>Soil erosion due to urbanization</td>
</tr>
<tr>
<td>9 (tie)</td>
<td>Xingtai, China</td>
<td>128</td>
<td>Coal combustion</td>
</tr>
<tr>
<td>9 (tie)</td>
<td>Baoding, China</td>
<td>128</td>
<td>Coal combustion</td>
</tr>
</tbody>
</table>

Conclusion
To ensure that students are prepared for the grand environmental engineering challenges of the present and future, engineering educators can incorporate into the curriculum pollution prevention approaches, climate change analysis and mitigation strategies, the use of fundamental concepts to evaluate problems that occur at the nexus of media, and global perspectives. 

Melanie Sattler, Ph.D., P.E., serves as the Syed Qasim Endowed Professor of Environmental Engineering at the University of Texas at Arlington. E-mail: sattler@uta.edu.

References
An Introduction to Python Programming for Environmental Professionals

A brief primer to the Python Programming Language, which is widely used in data science and has significant potential for addressing many environmental topics.
Software, sensors, unmanned systems, and machine learning are becoming increasingly used for environmental applications such as monitoring water and air quality, assessing invasive species, and quantifying habitat losses. As a result, advanced computing skills are becoming essential for the management of environmental systems. Despite the importance of these skills for effective management of natural resources and the environment, many higher education programs provide little training in data science and computing skills needed to effectively make use of the new data revolution that is sweeping the planet. The educational curriculum needs to adapt to provide environmental students with the training in computing skills to address emerging problems such as climate change, energy sustainability, water and air quality degradation, and habitat destruction.

Software and data literacy is expected to grow in importance and will likely become a core competency for many environmental professionals. Universities need to rapidly create and grow a pool of skilled environmental data scientists to meet this demand. This article provides a brief introduction to the Python Programming Language, which is widely used in data science and has significant potential for addressing many environmental topics. Due to its popularity, Python already has a wide range of educational materials that can be extended to teach new skills that are increasingly important for environmental applications. An example application of Python for environmental modeling is presented that is publicly available for interested readers to explore.

**Python for Environmental Applications**

Python is perhaps the most commonly used programming language right now for data science on account of its readability and open-source nature, which provides flexibility and facilitates extensibility into new data domains. Languages described as “open source” can easily be modified to include new features and fix bugs. Python is designed to be easy to read and extend, which allows new users to perform complex tasks without having to re-invent the wheel.

In addition to Python or a data-focused language, other important software and data skills needed for data science are basic knowledge of the command line and revision control. Command-line knowledge is important because it underlies the interactions of operating systems, and code development often requires interactions with files and programs at this level. Familiarity with revision control software such as Git is needed for collaboration and development. Python (or R), revision control and command line skills are commonly taught at Software Carpentry workshops, which are provided free and run by volunteers (including the author) worldwide. The Software Carpentry curriculum provides a possible pathway for introduction of data science skills to environmental professionals.

I started using Python when I was searching for a language for a sediment remediation design application. I needed a programming language to make a user interface, manage a database of chemical and material properties, solve differential equations, and provide graphical output. I also wanted to be able to distribute the software to other users (environmental consultants) without an expensive license. Python and its auxiliary “libraries” provided all these features and many more. Libraries are bundles of code that provide new features to a Python installation. There are now over 70,000 libraries in the Python Package Index, including many environmental applications.

Table 1 summarizes some important libraries that are available in Python for environmental and data science applications. Having all these features in a single language facilitates usage of Python as “glue” to connect disparate applications. For example, I have developed additional libraries in Python to automate the entire process of constructing a hydrologic model, including the scraping of data from online websites, processing input time series, performing geospatial calculations, and calibrating hydrological models.

Python can be used for scraping data from online databases, performing advanced mathematics, visualizing environmental data, and developing machine learning models. Machine learning is a tool that can make connections between disparate datasets such as those encountered in environmental systems that is being used in almost every aspect of modern life.

There are many different interfaces available to run Python

<table>
<thead>
<tr>
<th>Python Library</th>
<th>Environmental Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Numeric Python (NumPy)</td>
<td>Solution of linear system of equations, Image processing</td>
</tr>
<tr>
<td>Scientific Python (SciPy)</td>
<td>Statistical analysis, numerical integration methods,</td>
</tr>
<tr>
<td></td>
<td>solution of differential equations</td>
</tr>
<tr>
<td>Math Plotting Library (Matplotlib)</td>
<td>Data visualization</td>
</tr>
<tr>
<td>Python Data Analysis Library (Pandas)</td>
<td>Database queries, time series manipulation</td>
</tr>
<tr>
<td>Geospatial Data Abstraction Library (GDAL)</td>
<td>Geographic information system data processing</td>
</tr>
<tr>
<td>Scikit-learn</td>
<td>Machine learning</td>
</tr>
</tbody>
</table>
The easiest way to start working with Python is through the usage of Jupyter notebooks. Jupyter provides an interactive platform for coding and software demonstrations through a web browser interface that is ideal for educational purposes. The Anaconda Python Distribution includes common scientific Python packages, as well as many of the packages related to data analytics and big data. Downloading and installing Anaconda allows immediate access to the standard Python libraries as well as many of those listed in Table 1.

Jupyter allows for basic text formatting using Markdown, which is a language used on web pages that enables formatted output including headings, bullets, numbered lists, and tables. Complex mathematical expressions can also be developed in Jupyter notebooks using LaTeX syntax. These tools enable rapid development of environmental models, including documentation. If environmental education programs provided an introduction to an application-focused language in an environment like Jupyter early in a course in the curriculum, then reinforced their application throughout the environmental coursework, students could learn how to apply these tools and develop more advanced computing skills needed for complex environmental systems later. Environmental professionals could also learn these skills through professional development workshops.

Figure 1. Application of a Markdown cell to create a heading for a Python application in Jupyter.

Figure 2. Interactive Python coding cells in Jupyter that define variables, assign values, import libraries, and write functions and intermixed with Markdown description cells.
A Jupyter notebook has been made accessible online that shows how Python can be used to build an interactive version of the Streeter-Phelps model and placed in a Github repository for public access. Figure 1 shows the heading of the notebook before and after the Markdown code is converted into output in the web browser. The figure illustrates how to develop a header, table, and equations in Jupyter by writing Markdown code on the left and the resulting formatted results on the right.

Figure 2 shows four cells that demonstrate how to import libraries (NumPy) and write functions, which in this case are the DO and BOD as a function of the distance and other Streeter-Phelps model parameters. Figure 3 shows how to create a plot of the model output values every 0.2 km for a 50 km river using Matplotlib, which can be placed in-line in Jupyter notebooks. The graph illustrates that for these model parameters, the DO drops below healthy levels of 5 mg/L for about 15 km of this reach of the river.

This example shows how to build a documented, modifiable interface to a model in only 20 lines of Python code. Additional examples can easily be developed for air quality and other environmental models such the Gaussian Dispersion model for point sources, box model, etc. A variety of papers have been published recently describing ways to use Python for environmental data science problems.

Environmental education needs to embrace the new data revolution, which has potential to help solve many challenging issues. Data science tools can be used to describe complex environmental models, document parameters and equations the models utilize, and illustrate the model output with spectacular visuals. Jupyter notebooks that make use of Python can be published online and distributed to model users using Github. Approaches such as the example in this article can be developed to illustrate to students how to use software and data science tools to study environmental applications. Other important skills include command line usage, revision control, and high-level languages such as Python, Matlab, and R.

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**Example Application of Python for Environmental Management**

An example application of the usage of Python through the Jupyter environment is provided here to illustrate one approach to introduce coding and data science to an environmental student audience. The Streeter-Phelps Model is a famous water quality model taught in introductory environmental engineering classes. It relates the dissolved oxygen (DO) concentration $C$ and biochemical oxygen demand (BOD) $L$ at location $x$ downstream from a point source with initial DO and BOD concentrations $C_0$ and $L_0$, degradation rate $k_D$ and re-aeration rate $k_r$.

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**Figure 3. Application of the Matplotlib library to create an embedded graph of model results in a Jupyter notebook.**

**David Lam pert, Ph.D., P.E.,** is an Assistant Professor with the School of Civil and Environmental Engineering at Oklahoma State University. E-mail: david.lam pert@okstate.edu.

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This article discusses the key characteristics of Generation Z that directly influence their attitude toward education and compiles a number of teaching and learning strategies that have been widely suggested by educators to enhance the educational experience of Generation Z students.
Generation Z is the demographic cohort after the Millennials, defining individuals who were born between the mid-1990s and 2010. The name “Generation Z” was first suggested by readers of USA Today during an online contest in 2012, other names like iGeneration, Gen Tech, Gen Wii, Digital Natives, and Post-Millennials have been widely used in the literature and by different organizations. Generation Z represents approximately 25% of the U.S. population, surpassing the Baby Boomers (born between 1946 and 1964) and Millennials (born between the early 1980s and mid-1990s) cohorts in size. Generation Z’s birth years overlapped with various technological advances, including the widespread availability of wireless Internet access and the explosion of handheld technologies (e.g., smartphones, tablets, etc.), as well as socioeconomic trends (see Figure 1). The attitudes of this generation have been greatly influenced by the aftermath of September 11, the economy crisis of 2008, rise in unemployment rate between 2006 and 2009, and public shootings.

### Generation Z Characteristics and Expectations

Generation Z grew up in an Internet world, in which they learned to be comfortable with technology and social media from a young age. Even though Millennials are skilled in technology, how Generation Z has had access to information and consumed it, at an early age, is unprecedented. In 2014, it was reported that 41% of Generation Z spend more than three hours per day on their computers for non-schoolwork-related purposes. A survey by Pew Research Center showed that about three-quarters of teens own or have access to a smartphone, and only 12% of 13–17 year-olds have no cell phone of any type. The use of social media such as Facebook, Instagram, and Twitter has become an inseparable part of most Generation Z teens’ daily life, mainly to keep in contact with friends and to develop new relationships.

Today’s youth have all the world’s information at their fingertips thanks to smartphones, laptops, smart TVs, and tablets, to which they allocate a great portion of their time. It has been reported that Generation Z spend around 9 hours per day on their cell phones. As a result, Generation Z expects everything on demand, anytime, anywhere, without the need to wait. Another interesting trait of Generation Z is that they prefer things being tailored for them, from Netflix and YouTube shows to food at restaurants. This is not strange since their entire lives they have received information, services, and suggestions based on their preferences. Generation Z’s excessive reliance on the digital world and technology has led to the cohort’s common characteristics, including limited social skills, high risk of depression, and short attention spans. For instance, a survey of Canadian media consumption conducted by Microsoft showed that the average attention span had fallen to eight seconds in 2013, down from 12 in 2000.

A major percentage of Generation Z are children of Generation X who struggled with the economic recession of 2008. Consequently, being raised by skeptical parents in environments that might have been affected by financial and social stresses has led Generation Z to be, among other things, independent, cautious, pragmatic, insecure, and inclined to entrepreneurial careers. In this regard, a 2013 survey by Ameritrade revealed that 47% of Generation Z students in the United States were worried about their student debt,
and 36% thought they would not be able to afford a college degree. On the positive side, Generation Z is in general more risk-averse compared to Millennials, as might be judged by their lower alcohol and drug abuse, lower teen pregnancy rate, and higher high school graduation rates.\textsuperscript{17,18} Another key characteristic of Generation Z is their tendency to alter their identity to better blend in and cope with the environment or people they interact with (referred to as “situational identities”).\textsuperscript{19}

**Teaching and Learning Strategies for Generation Z**

Generation Z think, behave, learn, and function differently from their predecessors. Educating this generation can be made more effective if educators appreciate these differences and adopt novel teaching strategies that take into account what Generation Z students really care about and how they prefer to acquire knowledge. Considering the age range of Generation Z in 2019 (9–20 years old), its early members have recently entered higher education, while those closer to the end of the cohort will enter in the coming years. While early members would more likely resemble Millennials, later members of Generation Z would be expected to have more distinct and accentuated characteristics compared to generations before, necessitating fundamental changes in teaching methods.

In the remainder of this article, we discuss some of the strategies and suggestions that have been put forward by educators, researchers, and Generation Z students themselves to prepare higher education communities to deal with, engage, and educate Generation Z students. The recommendations elaborated below are by no means an exhaustive list. It should be noted that not all of these methods would be suitable for all students and/or circumstances; thus, they require some experimenting and testing with different groups of Generation Z.

The most influential characteristic of Generation Z when it comes to education is their craving for technology and the digital world. Most Generation Z students expect all teaching and learning resources to be available on online portals, allowing access to course materials on their electronic devices anytime, anywhere. In order to meet the educational demands of Generation Z, universities and colleges must equip their facilities with digital textbooks, digital projectors, interactive whiteboards, and associated mobile device apps.\textsuperscript{15} In addition, class updates and campus events can be posted on social media—Facebook, Instagram, Twitter, and LinkedIn—media that students use anyway for their personal or professional relationships.

Colleges and universities can even further shift from traditional teacher-centered lectures toward more active and blended learning strategies. Given the fact that Generation Z is highly accustomed to technology, educators can incorporate software, electronic learning materials, online animation/interactive material, and even interactive games into
their curricula. For instance, Sanmugam et al. employed a gamification platform as a mediator for Generation Z students who were learning science. Based on interviews with the participants, they found that gamification can boost students’ interest in learning. After being used for about two decades, learning management and virtual learning environment systems (e.g., Moodle and WebCT/Blackboard) currently are mainstream education tools and their use in teaching is expected by students.

Evidently, Generation Z students prefer to learn about a concept or subject through observation rather than reading about it in a traditional textbook. Therefore, it could be helpful and more engaging for educators to present at least part of the course content via videos, digital images, and visual diagrams. In this context, Murillo-Zamorano et al. showed that flipped classroom, a student-centered learning method, can positively affect students’ knowledge, skills, and engagement. In another study, Freeman et al. analyzed 225 reports on performance of undergraduate students in science, technology, engineering, and mathematics (STEM) courses in order to compare traditional lecturing and active learning. The results indicated that examination scores increased by 6% when active learning sections were applied, and that students in classes with active learning were much less likely to fail.

Moreover, rather than banning smartphones in class, professors can embrace them and use them to communicate with students via student response systems (e.g., Poll Everywhere, Mentimeter, AnswerGarden, TurningPoint), gathering instant feedback. Considering Generation Z’s need for immediacy of information and their short attention spans, the learning process needs to be more self-directed and project-based to effectively engage students. For individuals with a lack of focus, information should be conveyed in small quantities using different modalities such as lecture, discussion, and videos.

Generation Z students typically expect to have everything personalized, including education. Although it is impossible for professors to tailor lectures and assignments according to each student’s preferences, for some assignments educators can provide a list of activities (e.g., oral presentation, poster presentation, case study, short paper, etc.), all with the same learning objectives, from which students can choose their favorite. Additionally, if deemed effective, students should be allowed to study/work alone and at their own pace using self-study materials, such as online tutorials and videos. It may be more convenient and appealing to Generation Z students for instructors to substitute virtual office hours for in-person office hours, or to provide both options. Students can contact the educator using online video conferencing platforms such as Google Hangouts or Zoom to discuss their problems and also receive tutoring in an electronic format such as video clips or digital gaming.

Compared to Millennials, Generation Z students are typically more pragmatic, and their view of learning is quite different. Generation Z students desire to acquire skills that are vital to
their future jobs, and they prefer to apply their educational experience to solve real-life problems. To answer Generation Z’s aspiration in this regard, faculty can assist students to take several internships during their years in college by offering on- and off-campus internship opportunities that accord with their experience.11 Generation Z students prefer intrapersonal learning since they can better focus, study at their own pace, and also learn the subject well before having to discuss it with others.14 To incorporate this preference into group experiences, educators might consider several individual “checkpoints” throughout a project, allowing students to think through a problem/concept by themselves before asking them to contribute to group “checkpoints.”15

Conclusion
Generation Z students can be characterized by a number of unique traits: accustomed to technology and digital world, pragmatic, individualistic, independent, cautious, having a short attention span, and a strong desire for immediacy and convenience. These traits and attitudes greatly affect how they prefer to learn and to what educational approaches they respond well. Universities that understand the educational demands of Generation Z and design their curricula delivery accordingly will be successful. Educators who reconsider their teaching strategies and integrate technologies that are widely used by Generation Z students will be more successful at engaging and motivating them. Educators can maximize the use of visually based content instead of solely emphasizing textbook reading and traditional presentations. Finally, higher education courses that boost project-based, practical, student-centered, and experiential course components will provide students more freedom in learning, encouraging innovation, and critical thinking.

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Many scientists credit a teacher with helping inspire them to pursue a career in science, technology, engineering, and mathematics (STEM). A hands-on demonstration or experiment with a connection to real-world challenges can make textbook studies come alive with renewed importance and possibility for students, plus illuminate career paths not previously considered. As the U.S. Environmental Protection Agency (EPA) celebrates its 50th anniversary in 2020, our agency will be highlighting scientific contributions to public health and environmental protection. Part of this celebration will include our scientists and engineers sharing their scientific knowledge and how EPA science has contributed over the past 50 years to better understand and tackle environmental issues.

EPA researchers are involved in a variety of STEM outreach activities with schools and students of all ages. They share their knowledge at workshops designed for students and visit classrooms, museums, educational fairs, and other venues to connect the public with environmental stewardship and opportunities in environmental science. Some researchers have even created innovative environmental education activities hoping to inspire the next generation of environmental professionals.

International Outreach
EPA’s STEM resources also further international science diplomacy through programs such as the U.S. State Department’s Embassy Science Fellowship (ESF) Program. The program offers U.S. Embassies an opportunity to host a scientist for a short period of time, who will provide expertise and assistance with science and technology-related issues. Several EPA staff who have participated in the program have taken with them EPA-developed hands-on environmental education and STEM resources.

Recent ESFs include:
- **Kelly Witter**, EPA’s Research Triangle Park, North Carolina, STEM Outreach Program Manager, as an Embassy Science Fellow at the U.S. Embassy in Bosnia and Herzegovina taught 650 students and educators how to improve air quality and protect health at 11 schools.
- EPA Scientist **Dr. Rachelle Duvall** was stationed at the U.S. Embassy in Canberra, Australia, where she shared her
expertise on air quality and climate change, while also engaging in STEM education and encouraging students to consider careers in STEM fields. Dr. Duvall also extended this STEM-education support to the U.S. Embassy in New Zealand working with a local university and indigenous students.

• EPA Scientist Beth Hassett-Sipple collaborated with the U.S. Embassy in Bosnia and Herzegovina to design and champion programs to improve awareness of the health impacts of air pollutants, specifically particulate matter. She developed innovative strategies for communication of scientific information to key stakeholders, including medical health professionals, policymakers, and the general public.

• Dr. Lester Facey, EPA’s National Program Manager for Minority Academic Institutions, worked with Togo’s Ministry of Education to develop their STEM initiatives. He evaluated STEM education in schools, and teacher colleges throughout the county.

Outreach at Home
Several of the unique STEM resources and activities developed by our staff are now being used in outreach in U.S. schools. The educational resources include:

• **Generate: The Game of Energy Choices.** This educational board game is a fun way for students and others to explore what energy choices mean for our air, water, and future environmental quality. With no “right answers” the game allows students to develop evidence-based decision-making as they advocate to team members their preferences for the energy mix and calculate and compare costs of their solutions. Materials to make the game board and game pieces, along with middle and high school teaching guides are available free at www.epa.gov/climateresearch/generate-game-energy-choices..

• **Build Your Own Particle Sensor Kits.** This hands-on learning activity teaches the basics of particulate matter air pollution, air quality, and electronics while building problem solving and other STEM skills. Targeted for Grades 5–12, students can build their own particulate matter sensor. The instructions are available free at www.epa.gov/air-research/air-quality-and-energychoice-stem-activities-educators and include a materials list, an instruction guide with background information on air quality and the Arduino code for the sensors.

• **EnviroAtlas** (featured in a February 2019 EM article; http://pubs.awma.org/flip/EM-Feb-2019/epareshighlights.pdf). This web-based tool combines maps, analysis tools, and interpretive information on ecosystem goods and services to support sustainable and healthy communities. A suite of free K-15 EnviroAtlas Educational lesson plans and resources were developed that leverage the mapping tool and adhere to State Science Educational Standards. Six mini-lessons (www.epa.gov/enviroatlas/enviroatlas-educational-materials) for Grades 4–6 have been added to introduce the concept of ecosystem services in a blended learning format.

STEM Student Design Competition
EPA’s People, Prosperity, and the Planet (P3; www.epa.gov/P3) Program, a successful STEM education program, is a national design competition that provides teams of college and university students with grants to turn their creative ideas for environmental solutions into a reality. The student design competition highlights the use of scientific principles in creating innovative projects focused on sustainability, providing a practical application of STEM to environmental issues.

The two-phased program provides students with an initial grant of up to US$25,000 to test, research, and develop innovative scientific projects or engineering designs to promote sustainable development. P3 student teams then showcase their designs at the EPA’s P3 Expo and compete for an additional grant of up to US$100,000 to further develop and demonstrate their sustainability projects and designs.
The U.S. Supreme Court decided many important administrative and regulatory law cases during the 2018–2019 term, but perhaps its most significant decision, Kisor v. Wilkie, Secretary of Veterans Affairs, was decided late in the term on June 26, 2019. The court’s decision in Kisor should affect the judicial review of many federal regulatory actions, including environmental matters governed by the U.S. Clean Air Act, Clean Water Act, and Resource Conservation and Recovery Act (RCRA), which could have significant consequences on the regulated community.

Kisor involves “Auer deference,” a decisional doctrine created by the court in 1997, which allows courts to defer to—and usually approve—a federal agency’s reasonable interpretation of its own “genuinely ambiguous regulations.” The Kisor case concerned the U.S. Department of Veterans Affairs’ interpretation of an ambiguous veterans benefit rule that had been affirmed by both the U.S. Court of Veterans Appeals and the Federal Circuit. However, the court vacated and remanded the ruling.

Auer deference’s lineage can be traced to an older Supreme Court administrative law decision, Bowles v. Seminole Rock & Sand Co., issued in 1945, concerning the interpretation of a World War II price control regulation. The 1997 Auer case (Auer v. Robbins) involved another routine agency action—the Secretary of Labor’s interpretation of federal overtime...
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rules. Consequently, Auer deference has had particular utility for the courts inasmuch as they review thousands of such decisions made every year by federal agencies and executive departments.

As noted by Justice Gorsuch in his long concurring opinion, the federal “administrative state” is governed by the Code of Federal Regulations (CFR), which in 2018, “filled 242 volumes and was about 185,000 pages long”. Auer has eased the burden of reviewing many controversies regarding these rules because when it is clear to the court that the agency had the legislative authority to issue the rule, the only question for the court to decide is whether the agency reasonably interpreted its own regulation. However, over the years, some members of the court questioned the propriety of this doctrine because, in practice, it cedes much of the courts’ constitutional power to decide cases to the federal bureaucracy. In addition, some argue that this doctrine conflicts with the judicial review provisions embedded in the Administrative Procedure Act (APA).

Auer deference is not be confused with another decisional doctrine, Chevron deference, which relates to an agency’s interpretation of the statutes it implements and enforces. The court in Chevron held that a court’s review of an agency’s interpretation of the statute the agency administers should proceed, first, by employing the traditional tools of statutory construction to determine, whether Congress has directly spoken to the precise question at issue, and if not (because the law is silent or ambiguous), then the court must determine “whether the agency’s answer is based on a permissible construction of the statute.”

The Decision in Kisor v. Wilkie
As explained by Justice Kagan, Auer deference is rooted in the presumption that Congress would want the agency, as author of an ambiguous regulation, to interpret its own rules. The court’s reasoning lies in the assumption that the author of the regulation in question is in the best position to interpret its intent and meaning. Justice Kagan presented three rationales to support the court’s reasoning. First, rule-making agencies are privy to specialized technical knowledge that allow them to best weigh the costs and benefits of a certain interpretation. Second, the court acknowledges an agency’s unique ability to conduct factual investigations, consult with affected parties, and consider the historical handling of the rule in past situations. Finally, the court reiterates that if the agency is the one body to interpret the rule, the ambiguity would be resolved uniformly rather than by the dreaded “piecemeal litigation.”

After establishing that the court would not overturn Auer, it imposed limitations on the doctrine’s applicability by acknowledging certain circumstances in which Auer deference should not apply. The Chief Justice summarized the tenets of the revised Auer doctrine: the underlying regulation must be genuinely ambiguous; the agency’s interpretation must be reasonable and must reflect its authoritative judgment; and the agency must take account of reliance interests and avoid unfair surprise.

According to the court, a regulation is ambiguous if the reviewing court makes a diligent effort to uncover the regulation’s meaning but cannot do so. The court leaves the framework of “independent inquiry” open to interpretation.

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but outlines certain guidelines to provide a starting point. First a court should exhaust its “constructionist toolbox.” That is, the court should carefully consider the text, structure, history, and purpose of a regulation before resorting to deference. If genuine ambiguity remains, the agency’s reading must still fall within reasonable bounds of interpretation. The court must then make a final inquiry into whether the character and context of the agency’s interpretation entitles it to controlling weight.

The court emphasizes that the agency’s interpretation of its own rule must be its authoritative or official position. Furthermore, the interpretation must in some way reflect the agency’s substantive expertise. After all, the guiding premise of the doctrine is that the agency has some specialized knowledge that places it in a better position to proffer its interpretation than the court. Finally, the agency’s interpretation cannot create an unfair surprise to regulated parties. The interpretation must be a fair and measured reading of how the agency has imposed the rule in the past and stay in line with how the regulated parties have generally interpreted it.

However, what seemed to be the most compelling reason to uphold Auer deference was the court’s fidelity to stare decisis, and its reluctance to upset the settled expectations and outcomes that the long line of precedent made possible by Auer. These are important “reliance interests” that must be protected. The court concludes its opinion by remarking that Congress is well aware that Auer deference exists, and if this deference should be overturned, Congress has the ability to change the law.

Auer Deference Going Forward
Kisor’s continued impact on environmental regulation could be significant. Apart from the large body of federal health and welfare regulation located in CFR titles 20 and 42, the bulk of regulatory items listed in the biennial Unified Federal Regulatory Agenda are largely environmental issues. For example, the U.S. Environmental Protection Agency’s agendas, released as part of overall federal agenda, consistently lists many proposed and projected federal environmental regulations required by the Clean Water Act, the Clean Air Act, RCRA, Superfund, the Safe Drinking Water, and the Federal Pesticide law.

Accordingly, Kisor presages a gradual shift away from traditional Auer deference. Agency deference is not guaranteed, and lower courts that do not rigorously follow the new thresholds to deferring to agency interpretation will be chastened. Consequently, Auer deference is not invalidated, merely limited.

The court expects the lower courts will apply the new limits with rigor. This increased scrutiny may cause the courts and the agencies to proceed with caution, and the pace of regulation may slow while the agencies and the courts accommodate the “new” Auer deference standard.  

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This year, we celebrate 50 years of A&WMA's Annual Critical Review. For half a century, A&WMA has solicited and published in the *Journal of the Air & Waste Management Association (JA&WMA)* an Annual Critical Review on a topic of critical importance to the air and waste management fields. Each year, the review author presents the Annual Critical Review at a special session held during A&WMA's Annual Conference & Exhibition. Each month in this space, we will take a moment to look back at a singular review of critical significance from the past 50 years.


At the time of publication of this Critical Review, prevention of significant deterioration (PSD) had been a subject of study and discussion for approximately 10 years. Amid a growing level of interest in the subject, the 1977 review offered an extensive survey of the legislative and legal aspects of this concept.

The 1977 review (Vol. 27, No. 5) concentrated on what had happened to PSD during the prior decade. The review began with a chronology of PSD in the United States from pre-1970 activity to the present day (1977). The bulk of the review discussed the issues faced in developing and implementing PSD regulations and legislation in the United States, including air quality related issues, receptor related issues, and source related issues. In his conclusion, Dr. Stern touched upon some of the key drivers—or sticking points—of implementing PSD in the United States:

“This review has concentrated on what has happened and is happening to PSD during the last decade but has given very little space to why these things have happened. The why involves detailed discussion of political pressure, lobbying, deals, etc. More of this flavor comes through in the several law reviews of PSD (Table XXII) than in the technical reports listed in Tables X, XIX, and XX. The epitome of these actions was incorporated in a memo from a Deputy Assistant to President Ford to an Assistant to President Ford dated Sept. 28, 1976, outlining strategies that would ‘keep an unacceptable bill off the President’s desk,’ because it would be embarrassing for the President to veto an environmental bill in an election year. The filibuster on Oct. 1, 1976 accomplished this objective, even though it did not save the election.”

The author of the 1977 Critical Review, Arthur C. Stern, was a long-time member and Past-President of the Air Pollution Control Association (APCA), a forerunner of A&WMA. He made major contributions to *Journal of the Air & Waste Management Association (JA&WMA)* and his books on air pollution control are well-recognized nationally and internationally. Established in 2013, A&WMA now awards annually the Arthur C. Stern Award (www.awma.org/honors) for an outstanding contribution to *JA&WMA* in the fields of air and waste management.

The winners of the 2020 Arthur C. Stern Distinguished Paper Award, Drs. Hui Zhou, Aihong Meng, Yanqiu Long, Qinghai Li, and Yanguo Zhan, will be recognized at the Association's 113th Annual Conference & Exhibition Honors & Awards Ceremony in San Francisco, CA. The winning paper, “Classification and comparison of municipal solid waste based on thermochemical characteristics,” was published in the May 2014 issue of *JA&WMA*. em

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