A student engages in hands-on learning by taking measurements for a field experiment in Germany.

PHOTO: CHRISTOF STACHE/AFP/GETTY IMAGES

NEXTGEN VOICES

Imagining a teaching utopia

We asked young scientists who teach to **describe an effective learning experience they had as a student and then to imagine an ideal world in which teachers had the time, materials, funding, and support needed to consistently teach effective lessons.** Here, they explain how they would plan, teach, and assess lessons in this ideal world. Follow NextGen Voices on Twitter with hashtag #NextGenSci. **—Jennifer Sills**

Explore the world

As a student, my life was shaped by supportive teachers who applied the curriculum to nature and to life. If I had the support required, I would teach my botany classes in natural locations, where examples abound. The immersive environment would attract students' eyes, mind, and senses. Instead of serving as distractions, their phones could be used to take and share photos, inviting others to appreciate the species studied by the class. Students today could benefit from the ancient Indian tradition of teaching amidst nature.

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As a first-year student, I designed a short-term research project to answer a question about organism density on the rocky intertidal coastline of New Hampshire. This project allowed me to gain a sense of ownership in the process and gave me the confidence to identify as a biologist. Now an undergraduate biology instructor, I am a strong advocate for learning outside of the classroom in informal settings such as zoos, museums, and natural areas. These out-of-class experiences often increase students' motivation to learn and allow them to make new connections. In an ideal world, low-stakes assessments or discussions would replace formal worksheets in these out-of-class settings so students wouldn't feel restricted in the topics they could explore. I would also form partnerships with local organizations to collaboratively conduct research or citizen science projects as a class. Students could use the opportunity to delve deeper into biology, network, and engage in service opportunities within their communities. In this ideal world of teaching, these learning experiences would be made equitable: All students would have the ability to participate regardless of cost and transportation.

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Focus on communication

Structured, intentional focus on conveying ideas in the humanities helped me think more like an interdisciplinary scientist and discover the importance of communication. In an ideal world, I would teach a small environmental class focused on class discussion and written communication. Intentional interdisciplinarity in the design would help students explore crosscutting concepts and pressing issues. The writing would be in the format of real-world and professional activities, not typical classroom papers. Peer feedback would increase exposure to different types of writing and set students up for later success in collaborative research and team-based environments. The fundamental support provided would be time, which is crucial to teaching a feedback-intensive course.

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On my first day in calculus, my instructor asked us to use a given function to write a brief story describing the population dynamics of a wolf population on a remote island. The prospect of writing about math was unsettling; words and numbers were two distinct ways of knowing, or so I thought. In only a few short weeks I had come to appreciate the lesson that my instructor was imparting: Mathematics is a language like any other, with symbolism, nuance, and linguistic variation. This insight has been indispensable in helping me frame experimental design and scientific analyses throughout my career. In an ideal world,

I would hire enough professors so that introductory courses could be limited to a handful of students. The courses would focus on the language of mathematics and statistics and how communicating these concepts helps us communicate our science effectively. Communication activities, such as peer teaching, would be common, and assessments would include oral final exams and presentation defenses, activities that are usually relegated to advanced graduate academic training.

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Incorporate technology

Tutoring other students made me appreciate the value of taking an active role in learning. Students now have more access to information than ever but little understanding of what to do with it. In an ideal world, instead of banning technological devices from classrooms, I would teach students how to use them to boost learning. Future doctors, engineers, and scientists will excel not because of their great factual memories but rather because of their ability to find relevant information, solve problems, recognize bias, and think critically. I would plan my classes with hands-on experiments, debates, and analysis of real-life problems spanning chemistry, physics, and biology. Given that the best scientific solution may have a negative impact in the nearby community, I would also ask students to consider issues from historical, economic, and sociological points of view.

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When I was a student, I learned about sustainable development by playing a simulation game with other students. Similarly, I learned about game theory by participating in economic experiments using software to bargain with classmates. In an ideal world, I would create a virtual reality computer game (similar to the World of Warcraft) to teach students in real time. I would use an augmented reality game (like Pokémon Go) to encourage them to go outside during breaks to get some exercise. These immersive experiences would earn the full attention of students, making learning more effective.

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Provide practical applications

My high school physics professor inspired me to think critically about the real-world implications of basic physics concepts. This skill has been instrumental to me as a scientist. As an anatomy and physiology instructor, I strive to inspire my students as my physics professor did. In an ideal world, I would pique students' interest by beginning each unit with a discussion led by a physician and ending each unit with a cadaver dissection. To assess learning, I would ask students to describe how disruption of the organ system would affect the whole body or to debunk a common myth about the system.

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During my graduate studies, I had the opportunity to plan and execute biological experiments, which kindled my interest in becoming a scientist. Now, as a newly appointed professor, I hope to train my students to think independently. In an ideal world, I would incorporate student-centered hands-on lessons into the existing curriculum. After leading group discussions about the literature, I would encourage students to design experiments to test their ideas. Whenever possible, I would facilitate internships and industrial collaborations through which students would gain first-hand experience with the most updated scientific content and techniques.

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My evolutionary biology professor was late for every class. When he arrived, he would explain why. He told us about funding applications, meetings with PhD students, administrative tasks, a flood in the lab, and a wealth of other tasks that together provided a genuine picture of the scope of scientific work. Those informal moments, which made science seem less esoteric, less daunting, and more real, drew me into academia. Informally transferring knowledge about science requires exposure to actual practices. A teaching utopia would continuously supplement formal knowledge exchange with exposure to the informal elements of science, its social and moral structures, the physical and economic infrastructure, and the relationships built on trust that populate labs and departments. Students would participate in running labs continuously, engaging with administrative and technical staff, participating in lab culture, and experiencing devastating failure and uplifting success. Of course, such continuous apprenticeships would start modestly and become more ambitious over time, but they would start on day one of university instead of being tucked away in the last semester of the curriculum. Labs would have to grow, staff would have to be able to spend time on this, and experienced scientists would have to share credit with apprentices where sharing credit was due.

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Let students drive learning

As an undergraduate, I was encouraged to read the journal articles underlying each lecture of a Principles of Finance class. I supplemented my reading with relevant reference books to help me untangle the more complicated material. In my ideal financial markets class, I would provide students with enough background information to empower them to supplement lecture notes with outside reading. I would use a flipped classroom approach, in which groups of students would present papers related to the topic and related real-world problems. As assessments, students would use the tools learned in the course to address problems covered in newspaper articles.

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As an undergraduate, individualized lesson content and discussion with others who shared similar interests made me see myself as a scientist. In an ideal world, my lessons would be tailored to each student. Before the course began, each student would complete a comprehensive evaluation of their aptitudes, personalities, interests, and goals. Based on the results, I (and other teachers) would create an individualized course plan for each student. With sufficient teaching resources, each student would be paired with a teacher for one-to-one instruction. Students would also join study groups to meet with others who had similar course plans. The assessments would be tailored to each student's declared goals.

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