hering to well-known discoveries in cognitive science.

Gaps are not a problem in just the physics curriculum; they are pervasive throughout undergraduate education. One of us (Kevin) has taught the mathematics sequence from college algebra through differential equations and has seen the problem most clearly exhibited in trigonometry courses. Despite its elementary nature, trigonometry is an important recruiting ground for physical-sciences and engineering students: Class rosters are filled with students who show mathematical and scientific talents but have had poor guidance about how to apply them.

A typical trigonometry course is divided into three parts: trigonometric ratios and functions; analytic trigonometry, with its identities and equations; and applications and advanced topics. The courses tend to overemphasize part two, with classes wallowing for week after week in identities. As a result, advanced topics such as complex numbers, polar coordinates, and vectors aren't covered at all, and an opportunity to introduce concepts that physical scientists and engineers use extensively is squandered. Similarly, algebra courses will skip important material later in the textbook, such as an introduction to exponential and logarithm functions, because of lack of time. In a differential equations course, operational mathematics might be skipped.

In physics classes, instructors may eliminate topics such as hydrostatics or some of the introduction to fields—especially quantities related to the magnetic field—to make room for advanced topics that may be of more interest to faculty and students but actually do most students little good. Moreover, introductory courses in physics and in engineering will present vectors in somewhat different ways. Mechanical engineering students may not even take Physics I because the material is ostensibly covered in their statics and dynamics courses. So various cohorts of students entering Physics II possess different ideas and tools.

Winfrey posits that gaps in understanding result from instructors' attempts to build from specific to general ideas, and because of time constraints in most courses, the students never reach the general material. That approach, he writes, ignores the primacy effect: Material presented earlier is mastered better than material presented later. Textbook authors should therefore take the primacy effect into account and go from broad, general concepts to specifics.

Winfrey's suggestion runs into the somewhat unsettled realm of educational theory. Every teacher recognizes that students learn early course material best, but it isn't clear why. Many theories, all with some supporting evidence, attempt to explain the effect. For example, some researchers propose that information is easier to retrieve when it is subjected to occasional tests of recall, and early course content is tested more often.[1,2] Another theory holds that later course content exceeds the cognitive load that students are able to successfully process and store in their long-term memory.[3]

An introductory physics course will seek to teach students the foundations of electrostatics, in which time derivatives are zero. Winfrey's more general formulation of Coulomb's law brings in dynamical quantities. Although that formulation is in keeping with his general-to-specific paradigm, it runs counter to the idea of reducing unnecessary complexity in order to avoid cognitive overload.

Whatever the true sources of cognitive barriers in instruction turn out to be, all of us who teach mathematics, physics, and engineering can do better by learning what our customers—the students—need most and reordering or reemphasizing instruction to meet those needs. Possibly we can add big-picture generalizations, as Winfrey suggests, while also removing redundant material to avoid adding to the cognitive load. It is our responsibility as instructors to determine, in coordination with other departments, what is germane for each course we teach and to design our instruction accordingly.

References

1. E. J. Mastascusa, W. J. Snyder, B. S. Hoyt, *Effective Instruction for STEM Disciplines: From Learning Theory to College Teaching*, Jossey-Bass/Wiley (2011).
2. National Research Council, *How People Learn: Brain, Mind, Experience, and School*, National Academy Press (2000).
3. J. L. Plass, R. Moreno, R. Brunken, eds., *Cognitive Load Theory*, Cambridge U. Press (2010).

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A footnote on the founding of NSF

Emily Gibson's article "NSF and postwar US science" (PHYSICS TODAY, May 2020, page 40) was an enjoyable read. I have a personal footnote to add.

In 1954, as a graduating senior at the University of Wisconsin–Madison, I had been interested in solar astronomy even though I was majoring in physics. Joseph Hirschberg, Newell Mack, and I took a laboratory slate tabletop and other equipment to Mellen, Wisconsin, to observe an eclipse.

Although we did not get the information we wanted during that eclipse, another one was going to occur in the South Pacific in 1958. Groups from the High Altitude Observatory, the Sacramento Peak Observatory, and other facilities were planning to go there with support from the US Navy.

Julian Mack, who had been my senior thesis adviser, suggested that I write a proposal. He signed it, sent it to the Office of Naval Research (ONR), and then went off for an appointment as a scientific attaché in Sweden.

I received a letter from the ONR that they no longer provided general scientific support for the study of solar eclipses. But a new federal agency, the National Science Foundation, now handled such proposals, and the ONR forwarded my request. A while later I received a letter from NSF that included a check to fund the trip.

I took the check to the department chair, Ragnar Rollefson, who said he would have an account opened so that I could spend funds for equipment and travel. Time was short to have equipment dockside at Naval Base San Diego for the navy to take it to Pukapuka, New Zealand, via Honolulu. So I asked George Streander, Mack's instrument maker, if he would sign on and help make the equipment to study the eclipse. I designed an observation hut and gave lumber estimates to the navy, which would get the wood in Hawaii. I also designed the optics and heliostat; George made castings and all the fine parts, and he suggested bearings and a drive system for the heliostat. Narrow band-pass filters, lenses, photographic plate holders, tools, and other items were ordered and purchased. The university carpentry shop made the boxes for the equipment, and we took them to the train station in Madison for shipment.

We were ready at Pukapuka, but the weather wasn't. Clouds prevented most of the observers from getting data, although the rocket launches from the ship deck were successful.

Later on, in the 1960s, I served as the program director for Solar Terrestrial Research at NSF while on leave from Los Alamos National Laboratory. And in 1973 NSF approved a grant for my study of the total solar eclipse over Africa aboard a prototype Concorde, whose supersonic speed allowed 74 minutes of observing the Sun's corona.

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Milutin Milanković's time in Serbia

In their article "Physics in the former Yugoslavia: From socialist dreams to capitalist realities" (Physics Today, August 2019, page 30), authors Mićo Tatalović and Nenad Jarić Dauenhauer wrote that "Although the region gave the world these eminent physicists"—referring to Jožef Stefan, Andrija Mohorovičić, Milutin Milanković, Nikola Tesla, and others—"all of them worked abroad." For Milanković, at least, that statement may mislead readers: Although he did work abroad, he spent most of his scientific career in Serbia.

Milanković (1879–1958) is best known for discovering the Milankovitch cycles, changes in climate driven by variations in insolation at midlatitudes caused by changes in Earth's orbit over tens of thousands of years. He studied engineering at the Technical University of Vienna and earned his doctorate there in 1904 with a thesis on reinforced concrete, a new material at the time. He worked in Vienna until 1909, when he accepted the chair in applied mathematics at the University of Belgrade. There he taught mechanics, celestial mechanics, and theoretical physics and developed his astronomical theory of climate.

Milanković was on his honeymoon in 1914 in his hometown of Dalj, in Croatia, part of the Austro-Hungarian Empire, when the empire declared war on Serbia in July. A Serbian citizen, Milanković became a prisoner of war. Due to pressure from Austrian scientists, he was released on Christmas Eve 1914, and he was offered two choices, to live in Vienna or in Budapest. He chose Budapest because, as he noted, "in Vienna everybody was starving." He returned to Belgrade in March 1919 and remained there until his death in 1958.

Milanković vividly recorded the above details in his extensive diaries, which the Serbian Academy of Sciences published in the 1950s. A small part was translated from Serbian into English by his son, Vasko, in *Milutin Milanković 1879–1958*, published in 1995 by the European Geophysical Society.

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Cold War particle-physics collaborations

Gerson Sher's book *From Pugwash to Putin*, reviewed by Rebecca Charbonneau in Physics Today's May 2020 issue (page 56), captures his experience as an NSF coordinator and sometime participant in US–Soviet scientific collaborations. But his telling omits significant other Cold War–era US–Soviet collaborations and participants—in particular, the entire area of particle physics.

One major participant was Wolfgang Panofsky, the force behind the creation of SLAC and its first director, an internationally known leader in particle physics, and a highly regarded adviser to policymakers in Washington, DC. Panofsky wrote of his role in international collaborations in his memoir, *Panofsky on Physics, Politics and Peace: Pief Remembers*, published in 2007, the year in which he passed away. In his book, Panofsky describes a trip to the Soviet Union in 1956—a year before the first Pugwash conference—when he and 14 other scientists were invited to tour a number of high-energy-physics laboratories. He writes that the visit initiated "a new era of communications in high-energy physics." It was during that trip that he met Gersh Budker, which initiated years of scientific collaboration between the two.

The next major step in particle-physics collaboration came in 1970: a joint high-energy-physics experiment at the Institute for High Energy Physics (IHEP) in Protvino, about 100 km south of Moscow. Darrell Drickey of UCLA and Edouard Tsyganov of the Joint Institute for Nuclear Research (JINR) led the project (see Physics Today, September 1970, page 18). I was a young postdoc in the UCLA contingent, which included six scientists and their families, several with young children. The Soviet group included Russians, Uzbeks, Poles, and a Romanian. We Americans lived in Protvino for six months, working through the long Russian winter, forming friendships, and creating indelible memories. Some of the participants got together a few years later at Fermilab to repeat the experiment.

The joint scientific endeavor was in the spirit of détente a full two years before Richard Nixon's 1972 meeting with Leonid Brezhnev, which Sher refers to as the start of détente. At the time, the IHEP proton accelerator was the highest-energy machine in the world, and the Soviets were keen to provide visibility for their scientific achievement and the science city constructed to house workers and guests.

As a junior member of the US group, I was not party to the behind-the-scenes negotiations to create the collaboration, which the 1970 Physics Today report describes as a years-long effort between the US Atomic Energy Commission and the USSR State Committee for the Utilization of Atomic Energy. I was told at Panofsky's memorial symposium at Stanford University in 2010 that he also was involved.

The story behind the UCLA–JINR partnership and the topic of US–USSR particle-physics collaborations would have added an important piece to the history that Sher endeavors to cover in his book.

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