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# 2024 David Halliday and Robert Resnick Award for Excellence in Undergraduate Physics Teaching Lecture: It's not business, it's personal. Teaching large classes, one student at a time

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# AWARDS

## 2024 David Halliday and Robert Resnick Award for Excellence in Undergraduate Physics Teaching Lecture: It's not business, it's personal. Teaching large classes, one student at a time

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"I can't help but see physics everywhere I go now." This quotation from students' evaluations summarizes what I consider to be the most important learning outcome. I will discuss our efforts to make introductory physics a meaningful and enjoyable journey rather than a survival experience in weed-out classes. There is no single recipe to achieve that, but I'll share some ideas and resources that we have created. Additionally, I will discuss several new outreach programs that we introduced with the help of our students. Outreach is not just a service that we provide for the benefit of the public; it is an integral part of the learning experience for the students. 
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It is my great honor to receive such a prestigious award from the AAPT—David Halliday and Robert Resnick Award for Excellence in Undergraduate Physics Teaching. Thank you to the AAPT and thank you to my colleagues who nominated me. I must admit that I didn't plan my teaching career carefully, but I knew I wanted to teach when I was 7. After that, I put my teaching career on hold for almost 30 years, working in a research-only role at the Institute of Applied Physics within the Russian Academy of Sciences. I had zero teaching experience when I arrived in the US. In 2003, I was offered the opportunity to teach a junior-level class on Atmospheric Thermodynamics at Texas A&M University. I had a class of 30 students—polite, respectful, with homework always turned in on time. I thought: "Wonderful! This is America!"

I finished my first semester with the highest evaluations in the department, and after teaching this class for 3 years, I considered myself an experienced instructor. Then, in 2006, I walked into a class of 100 freshmen. My first class was at 8 in the morning. It was also my students' first class at Texas A&M. Essentially, I walked into a room of 100 high school students. Who do you think freshmen expect to see as their physics professor? One of those guys in Fig. 1. Instead, they saw me. I started talking about the syllabus, rules, and expectations. No one listened. My first class was a complete disaster.

Since then, I never walk into a first-semester freshmen class alone. I always bring an exciting demonstration. You create this "wow" factor, and it helps you find the resonant frequency for that particular cohort of students. This experience taught me the importance of making every class interactive and memorable. I like to show physics demonstrations in class. They motivate students, and often, you don't need expensive equipment. Take a potato, take a kitchen knife, and do a demo on inertia! Fifteen minutes after my class, one of the students sent me a video from her dorm, where she was doing the demo with an apple instead of a potato. Her excitement at seeing the tip of the knife emerge beneath the apple was unmatched (Fig. 2).

My favorite quotation from the students' evaluations is: "I can't help but see physics everywhere I go now" (Fig. 3). It perfectly summarizes what I consider to be the most important learning outcome of introductory physics classes. When they sign up for the class, many of them expect it to be a nightmare! It is striking to see the same sentiments repeated over and over again: "I was very nervous when I signed up for PHYS 218 and 208 and worried that I would be so lost in this subject," "I had a lot of doubt in myself and I wasn't the strongest in Physics," "Physics is not my favorite subject and before this class I felt that it was difficult to understand," "I came into this course with expectations of great difficulty and also with no interest in the material."

"Nervous, worried, lost, doubtful, no interest"—these words reflect the "pre-existing condition": fear, self-doubt, and lack of interest that I must help my students overcome. No matter how large my class is, I always try to make each student's experience personal. I don't just teach a class; I

Fig. 1. Students' vision of a physics professor.


Fig. 2. Student performing the "potato and knife" demonstration with an apple.

teach individual students. I learn their names. In the very first class, I ask them to take a selfie and send it to me. This is a bonding experience for the students. From the start, they know that I care about each of them. A good class is always a dialogue, and I aim to establish this dialogue from the very first day. I believe there is no single "right" approach to teaching, but in any good classroom, there's a sense that everyone is working together.[1,2]

I do the same small but important things many instructors do: running up and down the lecture hall to make eye contact and seem less intimidating, and holding weekly help sessions where I slowly work through additional problems from past exams. Our team creates common exams with open-ended problems, which we grade together, following each student's solution line by line. We return the exams in the next class, along with feedback and a detailed rubric, while the material is still fresh in students' minds, allowing them to review the grading and understand their mistakes. I request a meeting with each of the students who did not do well on the first midterm, and together, in a one-on-one meeting, create a plan on how to improve their performance.

Fig. 3. Student's reaction to a balancing demonstration with a skyhook and a belt.

I don't take attendance. The largest portion of my students' final score comes from the midterms and the final exam. I consider attendance in my class a referendum on my performance: if they don't come, it means the class is not helpful, not interesting, or not a priority for them. When we returned to the classroom after the COVID-19 pandemic, I started recording my lectures and posting them on Canvas. During the pandemic, we conducted a study on student responses to changes in introductory physics learning due to the pandemic. We distributed a questionnaire to students enrolled in online summer courses at Texas A&M and UT Austin in 2020. More than 75% of respondents said they'd like recorded lectures and review sessions when classes returned to face-to-face instruction.[3] Our undergraduate student, Matthew Dew, now a graduate student at Cornell pursuing his Ph.D. in physics education research and an AAPT member, was the first author of this paper. Due to this demand, I post all my lectures, but the in person attendance is still high.

Students who sign up for my classes come from very different backgrounds and have varying levels of preparation. To help those in need master the material, we have created supplemental resources for different types of learners over the years.[4]

Such digital, multi-media, open-access resources that are always available and can be watched repeatedly at times convenient for students serve as one path to improving success in the introductory physics courses. These include 15 years of previous exams and 200 videos designed for various learning styles. When we were recording the short supplemental videos, Bill Bassichis, the author of the textbook *Don't Panic*, with his decades of experience teaching these classes, would narrate; then-graduate student Jonathan Perry would write on the board, and I, with my "Soviet past" and passionate opinions on how introductory physics should be taught, was in between. Despite our differences, the project came together, and students began using our videos. However, there was still a gap to fill, so I recorded dozens of detailed problem-solving videos, which we call "recitation videos" (Fig. 4).

I broke many rules when recording, including the main one—keeping videos short to accommodate the short attention spans of modern students. I did not worry about the length or entertainment value of the videos. To my surprise,

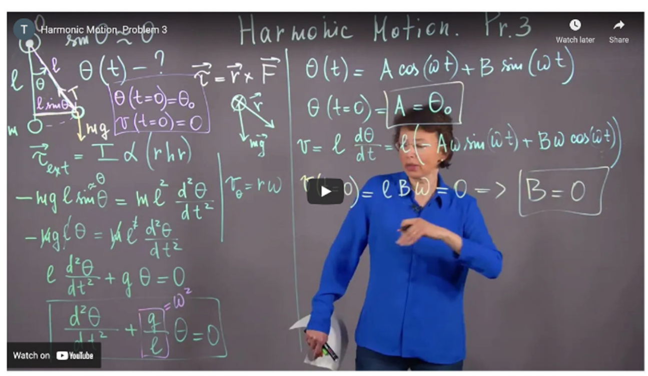


Fig. 4. A screenshot from a recitation video.

these videos became very popular with students, and many have attested that they helped them succeed in the course. Our team is studying the impact of the usage of the supplemental materials on student learning presented at the AAPT meeting by our graduate student James Hirons.

For introductory calculus-based mechanics, we further expanded our supplemental materials when we were included in the Texas Higher Education Coordinating Board's Digital Design for Student Success project. We created digital modules for each topic covered in the calculus-based introductory physics course. Each module includes a newly developed, textbook-independent homework problem set that can be delivered to students through the Learning Management System; supplemental videos with detailed, conversational-style problem-solving that explain the approach and address common mistakes; and video demonstrations of experiments for each module, allowing teachers and instructors to bring the excitement of physics experiments to their classrooms.[5] My colleague and AAPT member Dawson Nodurft was a co-leader on this project.

We all know that much of student learning happens outside the classroom. It has become my passion to engage students in informal physics programs, often called outreach or public engagement programs. I strongly believe that physics outreach is not just a service we provide for the public's benefit; it is an integral part of the learning experience for students. Over the years, we have created many programs aimed at enhancing our students' educational experience. One program that is very close to my heart is called DEEP, which stands for Discover, Explore, and Enjoy Physics and Engineering (Fig. 5).[6] Our students work in small teams, led by DEEP mentors (graduate students in physics), throughout the year. They design and build exciting new demonstrations, which they showcase at outreach events. These demonstrations are also used in regular classes.

For example, the team in Fig. 6 built a magnetic track with a superconducting train levitating above it. Most of these students were freshmen when they created this demo. In large introductory classes, it's easy for students to feel lost, but these students can always take pride in the fact that they built a demonstration that will be displayed for years. They left a legacy!

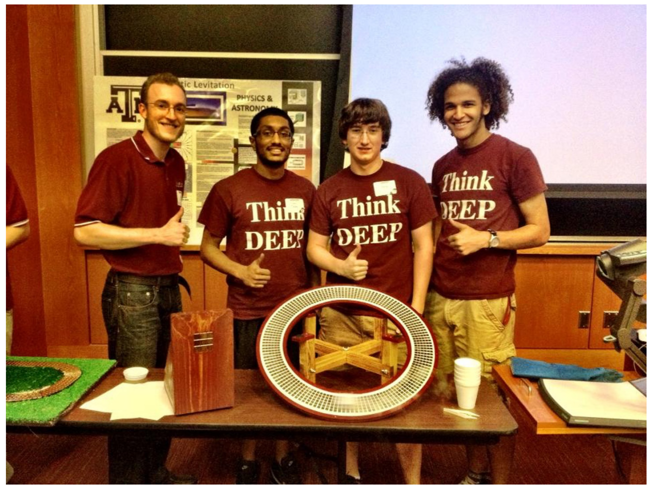


Fig. 6. The DEEP team that built a superconducting train track. Photo by Natasha Sheffield.

How do the graduate students who lead these undergraduates benefit from the program? They build collaborative research teams and lead efforts to accomplish and present their projects, replicating the research process in academia or industry. Many of our former students have started similar physics outreach programs in both academic and industrial settings, sharing their outreach expertise. Two former DEEP mentors, Michael Cone and Jonathan Perry who became instructional faculty at Rice University and UT Austin, started programs similar to DEEP there. I am no longer running the DEEP program at Texas A&M on my own; a former DEEP mentor and AAPT member, Dawson Nodurft, is now a co-leader of the DEEP program here at Texas A&M.

DEEP groups present their demonstrations at our flagship outreach event: the Texas A&M Physics and Engineering Festival[7] (Fig. 7). Six to seven thousand people attend our Festival each year, which features an expo with more than 200 interactive, hands-on demonstrations presented by our faculty, staff, and students. Our Festival is renowned for the record number of professors who participate, spending the entire day showing physics demonstrations to our visitors. They set an excellent example of public service for the

Fig. 5. Participants of the DEEP program at Texas A&M (Ref. 6).

Fig. 7. Depth charge demonstration at Texas A&M Physics and Engineering Festival (Ref. 7). Photo by Tim St. Martin.

Fig. 8. Texas A&M Physics Show (Ref. 8). Credit: Dave McDermand/The Eagle newspaper, July 2014.

students. The Festival also includes talks by world-renowned physicists and astronauts, as well as popular shows like the science circus and bubble demonstrations that visiting families truly enjoy. My favorite part is the grand finale: the Texas-sized five-barrel depth charge, where a small amount of liquid nitrogen sends a thousand colorful plastic balls flying up to the third floor, only to be eagerly collected by children after the explosion. When the pandemic hit, we did not give up; we organized a virtual festival, which was attended by thousands of people from across the country.

The Festival takes place once a year, but how do we maintain the enthusiasm for outreach throughout the rest of the year? We run 40–50 Physics Shows annually for K-12 students who visit campus, giving them the opportunity to enjoy and learn through hands-on demonstrations[8] (Fig. 8). It's amazing to hear their feedback, especially when second graders, both girls and boys, tell you after the show that they have "finally" made up their minds to become physicists!

Fig. 9. MIPEP teacher participants (Ref. 9).


Fig. 10. Physics demos at the football game.

We also "train the trainer" through a program designed for high school teachers and called Mitchell Institute Physics Enhancement Program (MIPEP)[9,10] (Fig. 9). Did you know that less than half of high school physics teachers have a background in physics? We select physics teachers from across Texas, many with little or no formal physics education, and provide them with 2 full weeks of rigorous physics training. This includes lectures, labs, hands-on demos, discussions, and tours. As part of the program, we share ideas for demonstrations that can be run on a zero budget using household materials in their classrooms. We stay in touch with these teachers, and they often bring their students to the Festival and Physics Shows. Our fearless leader is AAPT veteran Janie Head.

How do we bring science to people who might never visit a university campus on their own? We run programs like Just Add Science and Game Day Physics, taking our fun demonstrations to places where people are already gathered—home football games, heritage events, and community festivals—to share our excitement about physics (Fig. 10). Imagine this: street musicians, Texas food and wine, and … physics. Our physics students are like rock stars on the streets. Astronaut Serena Auñón-Chancellor even wore an Aggie Game Day Physics T-shirt aboard the International Space Station, a design created by one of our undergraduate students (Fig. 11).

However, some K-12 students do not have the opportunity to visit the Texas A&M campus, which is why we created

Fig. 11. Astronaut Serena Auñón-Chancellor wearing Game Day Physics T-shirt on the International Space Station. Credit: NASA.

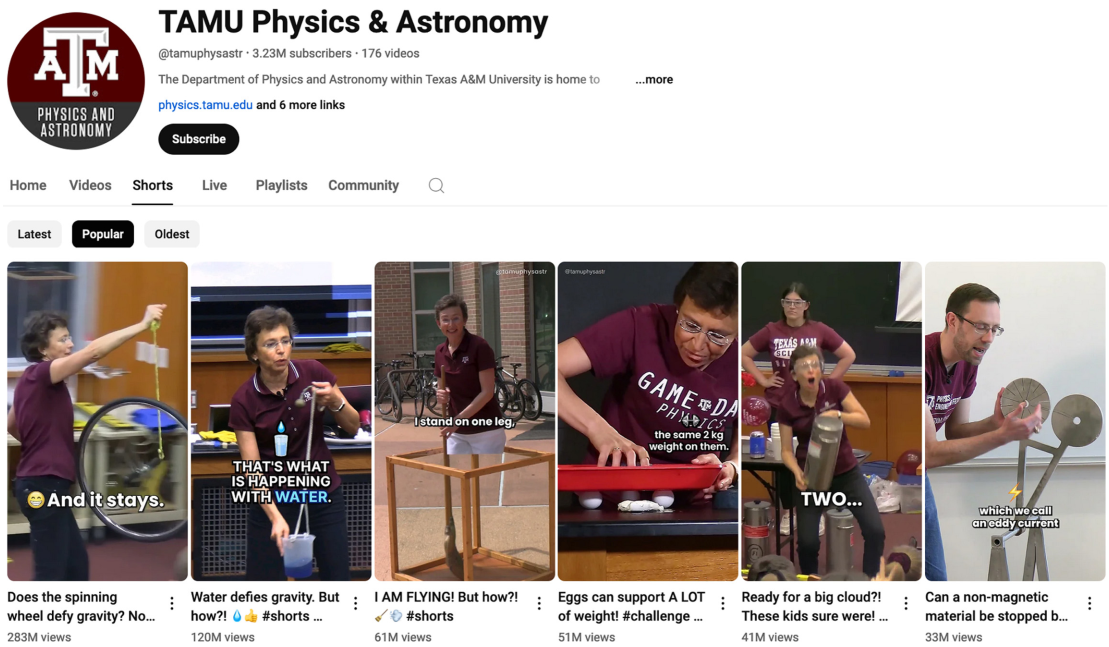


Fig. 12. Texas A&M Physics YouTube channel (Ref. 12).

videos for them. In the Real Physics Live program[11] sponsored by the American Physical Society, we produced short, entertaining videos about physics demonstrations, explaining the underlying physical principles. These videos are intended for middle and high school students, college freshmen, the general public, and all physics enthusiasts. Graduate and undergraduate students worked as a team to write the scripts and star in the videos.

Although I was a PI on this project, I never appeared in these videos. I speak funny—what's the point? So, when our talented marketing team posted a video of me performing the physics show on the departmental TikTok channel and it went viral, it came as a complete surprise! No one expected that! This sparked a new project, and we continued posting our short educational videos on departmental social media. For us, it was yet another way to communicate with people and make physics accessible and enjoyable. That's when we received a call from a local news station asking, "Did you know that on some social media channels, Texas A&M physics is more popular than Texas A&M football?" We had no idea. We are a very small team. It felt surreal. Then, out of the blue, TikTok was banned by the Texas governor for public universities. We did not give up; our web—marketing—social–media tsar shifted our focus to other platforms. We started posting on departmental YouTube, Instagram, Facebook, building a successful following on these channels.[12,13] Our YouTube channel has over 3 million subscribers (Fig. 12). One of our videos, a spinning bike wheel that we often demonstrate in our mechanics classes, has over 280 million views[14] (Fig. 13). Our videos have reached over a billion views on the departmental social media channels! We have received so many thankful and encouraging messages from people all over the world—Africa, Asia, Australia, South America, Europe, and, of course, the US, urging us to continue posting videos about our demonstrations. These videos are short; you cannot explain much but you can get people interested and willing to learn more. These videos also help break stereotypes that physics is hard and inaccessible.

This success on social media brought our demonstrations to Hollywood, to the Jennifer Hudson Show[15] (Fig. 14). CBS National News came to Texas A&M to film our programs and, most importantly, our student leaders in outreach[16] (Figs. 15 and 16).

Later, CBS invited me to their studio in New York for a live performance on their "Back to School" program at CBS Mornings[17] (Fig. 17). I was completely terrified! They requested a demonstration that we often do in our introductory physics classes: a demonstration on the conservation of angular momentum. You stand on a spinning platform while holding a spinning bike wheel. When you flip the wheel's


Fig. 13. YouTube video with a bike wheel collected over 280 million views (Ref. 14).

Fig. 14. Physics demonstrations on the Jennifer Hudson Show (Ref. 15).

axis, both you and the platform start spinning to satisfy the conservation of angular momentum. My biggest nightmare was that I would fall off this platform on national TV and that the video would go viral for all the wrong reasons. Fortunately, I learned before the performance that there is no such thing as live TV—there is always a slight delay during which the producers can make adjustments. I did not fall off the platform, and the episode went really well. All three anchors were competing for a chance to do a physics demo! It was a unique and unforgettable experience!

When we discuss outreach events, we usually emphasize how much visitors and the community benefit from them. However, we often overlook the significant advantages our own students gain from these interactions. Students have the opportunity to serve the community by applying their knowledge and expertise. The best way to understand something is to explain it. Through communication with the public, students gain invaluable teaching experience. The dynamic and often informal setting of physics outreach programs encourages students to take ownership and fuels their enthusiasm for serving as science ambassadors. Explaining the physics concepts behind hands-on demonstrations improves their communication skills. Teamwork, design skills, networking within the department, and recognition from peers, professors, and the general public—these are all benefits provided by programs traditionally referred to as outreach. Such programs offer our students a priceless opportunity to develop

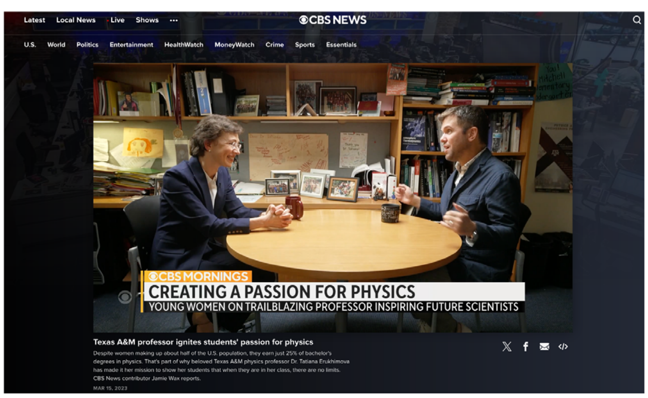


Fig. 15. Meeting with Jamie Wax from CBS Mornings (Ref. 16).

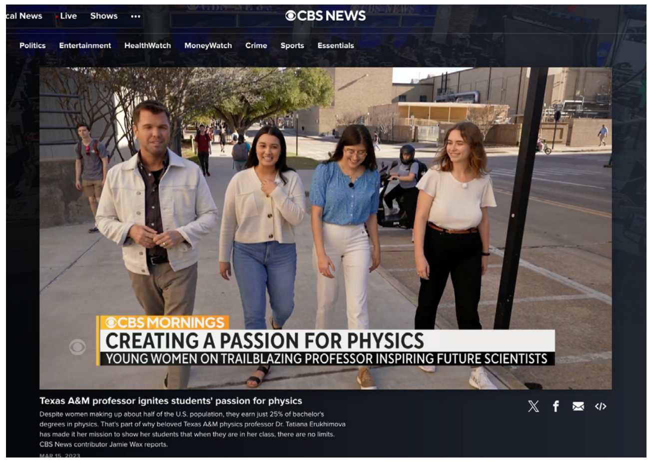


Fig. 16. Undergraduate students involved in outreach talking with Jamie Wax (Ref. 16).

their "physics voice," find their STEM identity, and gain new perspectives. This is not just anecdotal evidence; we conducted a study!

We surveyed and interviewed current and former undergraduate and graduate students who participated in outreach programs between 2013 and 2019. We analyzed the surveys and interviews, and the results were incredibly encouraging![18–21] Look at the map in Fig. 18. This is a network map that illustrates the ideas and their interconnectedness as expressed by Texas A&M students who facilitated our outreach programs. Motivation is at the center of this map, closely connected with communication skills, excitement, interest, teamwork, persistence, and becoming an expert. Students shared that participating in these outreach programs made them feel more connected to the physics community than they did through their classes alone. One student reported that "physics outreach activities have really made me feel like I can be part of the physics major." They also spoke about the improvement in their communication skills, noting that "if you're going to tell something to a 5-year-old and then something to a 65-year-old standing right beside them, they both have to understand it, but they each want something different. You have to learn how to speak on their level."


Fig. 17. CBS Mornings Show (Ref. 17).

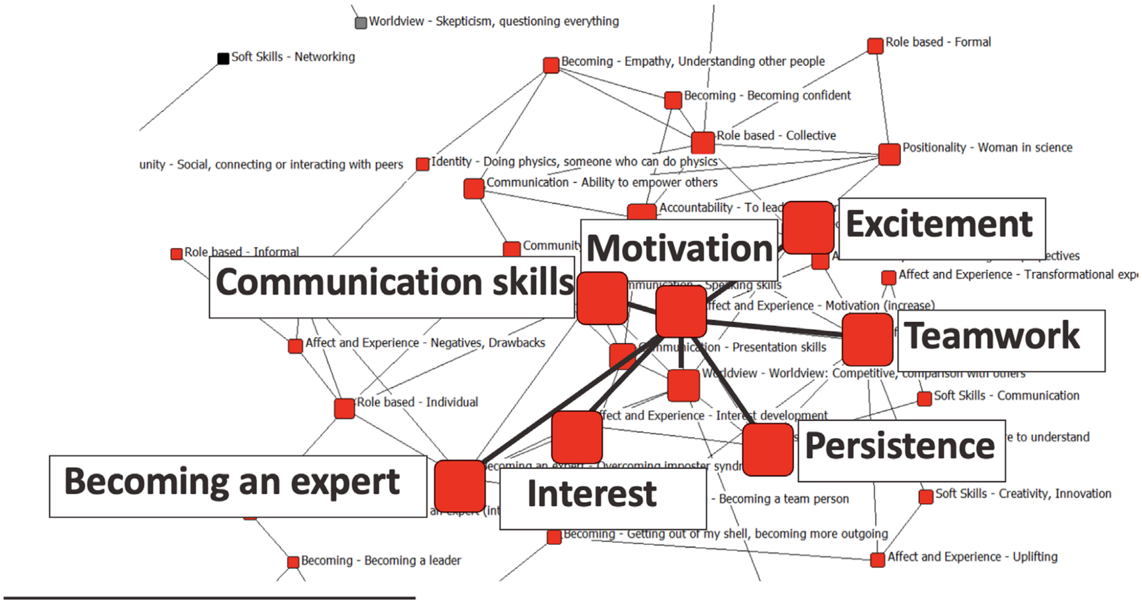


Fig. 18. Network map showing the relationships between the ideas at the level of $p < 0.01$, based on the data from Ref. 18.

Here are two final quotations I'd like to share with you: "[Informal physics programs] just make you feel more welcomed into the physics department and the physics community in general. You feel like you have a place where you belong, and you're contributing something. When you feel like you're contributing to a community, you feel more a part of it." Another is: "I wasn't sure if [physics] was a good fit for me, but I've definitely been reassured that it's something I want to do and something I can do—something I'm actually capable of." These last two quotes are from women who were freshmen at the time. We included all participants in this study. However, our analysis revealed unique impacts of outreach programs on female students, a group traditionally underrepresented in physics.[19] The leading authors of these studies were our undergraduate students, many of whom are current or former AAPT members.

Obviously, these studies have limitations. One limitation is that they come from a single university with a well-established outreach program. However, in collaboration with Jonathan Perry from UT Austin, Toni Sauncy from Texas Lutheran University, and the team led by Susan White at the American Institute of Physics, we are now exploring the impact of facilitating informal physics programs on a national sample of undergraduate physics students. The results are very encouraging. More to come—stay tuned!

When we prepare our classes, we do it in prose: we worry about the syllabus, learning objectives, pre-requisites. All these are important things. However, we teach in poetry. At the end of the day, what really matters is this: how many of the students taking my class today will remember it 20, 30, 40 years from now? How many of them will consider my physics class a highlight of their time at the University? If there are quite a few, I could not imagine a better reward. Thank you for the honor!

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## AUTHOR DECLARATIONS

### Conflict of Interest

The author has no conflicts to disclose.

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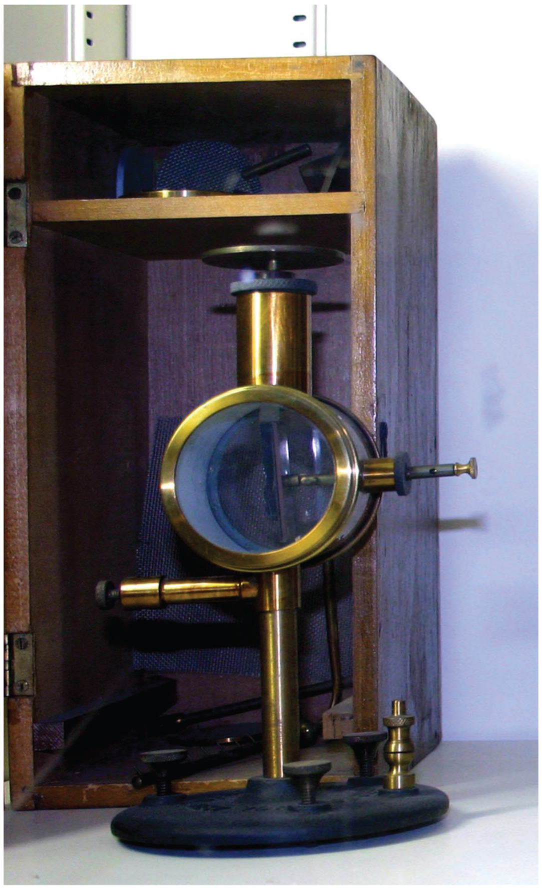

**Zeleny Electroscope**

This good example of a Zeleny electroscope was on display at the Rennselaer Polytechnic Institute in Troy New York when I photographed it in 2013. John Zeleny was a professor of physics at Yale University, and first described the apparatus in *Phys. Rev.*, 32, 581 (1911). The rate at which the electroscope leaf collapsed was proportional to the amount of ionization in the region between the grounded upper plate and the lower plate, attached to the gold leaf. This effect could be used for a number of experiments: ionization of air by alpha rays, ionization of air by beta rays, ionization by flames, a glowing splinter or a hot wire, the photoelectric effect and the range of alpha particles in air. (Picture and text by Thomas B. Greenslade, Jr., Kenyon College)