

Science Education Outreach: Physics Demonstrations, Lectures, and Workshops

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Anyone who spends even a short time helping children learn science soon discovers that they learn in many different ways. It is a challenge to respond to their diverse interests and backgrounds, but without that response, many children may get bored or left behind. A classroom teacher faces the additional challenge of needing to find materials and activities that engage children's thinking across a wide range of science topics.

This is where science education outreach comes in. Programs run by universities, museums, science centers, industry, and other organizations can greatly enrich learning for students of all ages, by providing materials and technical expertise few teachers could have. They enhance the curriculum by presenting science in new and exciting ways.

This article reports our evaluation of the highly-successful outreach program of the Physics Department at the University of Illinois, which is designed for teachers and students in grades K through 12. Our evaluation shows some surprising effects of this kind of science education outreach. Thousands of children have benefited, but many teachers could take better advantage of this and similar outreach programs if they knew more about what they can and cannot do. Although our study focused on the Physics Outreach, we believe that the findings have general implications for teachers and others involved in science education outreach.

The University of Illinois Physics Outreach

In recent years there has been a renewed awareness of the need for getting more students to like and understand science. This need is being addressed by a wide variety of outreach programs in a variety of settings, including both schools and community sites. These programs may involve scientists from industry or universities, museums, or university science students. Most emphasize hands-on activities for

teachers and children. For example, the Illinois-based Grow in Science program has teachers work in a summer science camp to develop better ways of supporting hands-on science learning in the classroom. In another Illinois program, Project SEARCH (Spectrum, Winter 1994), pairs of undergraduate science majors develop and present hands-on science projects for children at local schools and community centers. Each of these, and other programs throughout the country, operate on the premise that collaboration among scientists and educators is needed in order to address educational needs.

The outreach program of the University of Illinois Physics Department comprises several activities, including Physics Van Presentations, the Saturday Physics Honors Program, and Physics Workshops for Teachers.

Physics Van

The goal of the Physics Van (Spectrum, date) is to create enthusiasm and stimulate curiosity among students and their teachers, showing them that science is interesting, fun, and within their grasp. Three or four undergraduates in physics and physics education demonstrate basic physics principles using a variety of instructive and entertaining science demonstrations at elementary and middle schools, summer camps, boys and girls clubs, and other venues. Some of the Van demonstrations can be repeated by children on their own. Teachers receive descriptive material ahead of time and can request special topics to enrich and illustrate their lessons.

Students and teachers participate in the experiments whenever possible. The children impersonate solids, liquids and gases in a demonstration of atomic motion in the three states of matter. In another demonstration, they experience the sudden push backwards when they hold a fire hose in an experiment illustrating momentum conservation. They compete with an air vortex generator trying to blow out a candle. Even when they cannot participate directly, their attention is held by demonstrations like a nitrogen cannon, which illustrates the power of the expanding gas.

Saturday Physics Honors Program

A second component is the Saturday Physics Honors Program, a series of monthly lectures on modern physical sciences. The lecture series, now in its fifth year, is open to the general public, but directed primarily at high-school seniors. Through the program, high-school and college students and teachers meet world-class researchers in a relaxed, interactive setting, learn about recent advances in the physical sciences, see how physics underlies modern technology, and view its impact on our everyday lives. Topics include the physics of atoms at surfaces; chaos and nonlinear dynamics; black holes and computational relativity; planets, comets and their collisions; severe and unusual weather; atomic clocks and the global positioning system; and earthquakes and active mountain building.

Physics Workshops for Teachers

Physics Workshops for Teachers is a third major component of the outreach program. One set, called Fun with Physics, includes workshops that teach teachers about the physics underlying the Van demonstrations.

Another is Operation Physics (originated by the American Institute of Physics), a national program of in-service workshops intended to enhance grades 3-8 teachers' understanding of and comfort with physics, and to provide them with techniques and activities for teaching. The workshop leaders are local master teachers trained by Operation Physics personnel. The workshop experience is intended to enable teachers to give their students an improved understanding of the physics concepts that apply to everyday events.

Workshop activities begin by eliciting participants' conceptions about physical phenomena, then lead into hands-on participatory activities. Each module also includes a discussion of ideas that children can bring with them into the classroom. There are 13 topics: Matter and Its Changes, Measurement, Simple Machines, Magnets and Magnetism, Electricity, Light, Heat, Astronomy, Forces in Fluids, Forces in Motion, Sound, Color Vision, and Energy. The modules are designed so that each requires one day of training.

Evaluation

There have many positive response to the Physics Department Outreach, but no systematic study of its impact. In order to learn more about what teachers gained from a program like this, we conducted an evaluation, focusing on teachers' perceptions. We interviewed teachers, beginning with standard questions, but following up topics teachers felt were important. In addition, we used survey data and response forms collected from teachers participating in the Physics Honors program or Workshop sessions. The focus was thus on teachers' what they learned and how they valued the various aspects of the program.

Survey Results

The survey of teachers participating in the Physics Honors Program showed a remarkable positive response. Every teacher said that the Physics Honors Program was a useful option for their students and that they would like to participate again. One said, "Four of my students who have attended these are enrolled at the UI in science areas...your efforts are greatly appreciated and I look forward to participating in the future." Another said, "I liked the 'magic' problem at the beginning of the program. The students would come back talking about it. Teachers identified several specific aspects of the program:

- a. The students are impressed with people on the "cutting edge" of physics applications;

- b. The students get to see that physics has many practical applications. They also learn that physicists are not "gray beards in ivory towers" and they learn about the most current research;
- c. Option to challenge those that have a keen interest. You are able to do things we cannot;
- d. The Everyday Physics section is excellent;
- e. Allows students to learn about current topics from "real" scientists and to see scientists and what they do;
- f. Exposure to current topics by people working in them;
- g. Exposure to modern topics and chance for students to hear presentation from someone besides daily instructor;
- h. They can ask questions to people who are experts in the field;
- i. Enrichment alternative for advanced students;
- j. Giving gifted students topics often not covered in class, "interest getting" of introductory labs.

There were very few recommendations for changes, despite the fact that several questions explicitly invited these. One teacher suggested the need "to add an informal reception after lectures to allow students to interact with presenter and each other." The biggest problem related to scheduling. As one teacher, said, "Scheduling conflicts constantly arise. We have so many different organizations with so many various events it would be nearly impossible to schedule without conflicts."

Interviews with Teachers

We randomly selected a set of ten teachers for in-depth interviews. The fact that 18 of 24 attendees at one session volunteered to be interviewed is one indication that most saw some value to the program, and the consistency of responses suggests that our interviews did identify issues of common perception among the teachers. It is worth noting that the preliminary response form especially encouraged complaints: "Please let us know what you found to be the high points and low points of the workshop. Do you have any specific suggestions for improvement?"

One teacher who did not wish to be interviewed wrote this on the response form in place of the contact information that would have indicated willingness to be interviewed:

I am not involved in this field even remotely. I came out of personal interest and growth...

I was very impressed with the high level of organization, great hand-outs which matched over-heads and can be re-used, and good delivery of speaker.
Excellent!

Reactions to Physics Outreach

The interviews revealed generally positive and often surprising responses from the teachers. Like those who responded to the survey, they were very positive about the benefits to themselves and their students from the program. This is noteworthy, in that we were able to follow-up with questions seeking to identify things they did not like.

Desire for more outreach programs. A universal response was that teachers wanted more opportunities like this. For example, the session on Operation Physics highlighted the fact that they would like the Operation Physics summer workshop to be held locally. Every interviewee thought that aspects of the program they were familiar with should be expanded and offered to more teachers, more often.

Responses of non-science teachers. One striking and somewhat surprising result was that non-science teachers seemed to derive much of value from the program. For example, a former Drama teacher who now teaches Kindergarten thought that the Physics Van was extremely valuable to both herself and her students. A middle-school English teacher said that the Particle Zoo presentation (part of the Physics Honors Program) was important to her professionally, because it validated her sense of herself as one who can learn new things. She also saw connections between the inquiry process in physics and the writing process she teaches to her students. On her response form she had written:

I am a lay person--an English teacher--with an abiding curiosity in science (a Ph. D. son in genetics) and Zen physics (The Dancing Wu Li Masters) sort of knowledge about quantum mechanics. This was an outstandingly clear (though fast) presentation that helped to fill in gaps in my knowledge gained through occasional "NY Times" Science pages and *Scientific American*. Thank you!

Intellectual stretching. A related point is that nearly every teacher commented that they liked being stretched intellectually. It appears that the Outreach Program provides a source of intellectual stimulation for teachers that is sometimes lacking in their day-to-day work activities. This general intellectual stretching result was not one that we had anticipated. In fact, the teachers almost seemed embarrassed to bring it up, focusing initially on direct curricular implications. But it was clear to us that more general benefits were important as well.

As an example, one teacher wrote on the response form at the Particle Physics workshop:

[It was] very well organized and presented. Not my field of study, but I feel I learned and got an overview of the current research. I especially liked having a presenter that is doing cutting edge/state of the art research.

One teacher talked about the value of collaborative problem solving in the Operation Physics workshop, for herself, not just as a teaching technique:

I remember spending a lot of time thinking about multiple circuits and how to get them to work so that you got the effect. And I really enjoyed that. We really had to think. We had to think not only about how the circuits would work, but what materials to use. But, it was fun to tinker at the time. And it was very nice to have other people tinkering with me at the same time, sharing ideas, sitting and saying, "These people don't know what they're doing," then suddenly I realize, "Oh! they know more than I do." Absolutely know what they're doing! And learning from them and vice-versa. So it was very nice to be able to work in groups and to utilize other people's minds to do that.

Thus, teachers viewed the presentations as opportunities for them to learn.

Connections to classroom teaching. One teacher connected her experience at the Operation Physics Workshop to her own teaching in this way:

I like those problems very much and I realize more what needs to be done at the school level. It's OK to teach them concepts, but then throw them a real problem.

Another said:

Advantage? Materials you can use immediately in the classroom without a lot of extra preparation. It's user friendly! It's hands-on. I really appreciate the opportunity.

Recommendations for Changes

The open-ended interview format allowed us to probe for recommended changes in a way that was not possible with the survey. We were thus able to identify recommendations in several areas.

Classroom preparation. A nearly universal theme in the interviews was the need for more preparation before the outreach activities, especially the Physics Van. Teachers felt that the Physics Van was exciting and meaningful for their students. Precisely because of this, they saw the possibility for building upon it, but needed help in doing so. They wanted to have students try activities in the classroom ahead of time or talk about the phenomena they might see. There is a value to the surprise produced by the Physics Van demonstrations that should not be dismissed. Nevertheless, it does seem that more reading, discussions, and classroom experimentation, at least on related topics, could prepare students for deriving the maximum possible from the event.

Classroom follow-up. Similarly, the teachers wanted there to be more follow-up activities to support integration with the classroom. In part, they wanted teaching resources. As one teacher said,

We did have a certain amount of stuff that was hands-on and that was very good. I would like to have more, things I could take home with me and tinker with at home.

Some specific ideas for follow-up included having children send in questions about the demonstrations via Email, having follow-up classroom experiments, having suggestions for activities teachers could do, and individual classroom visits by Physics students. One teacher even volunteered to serve on a teacher committee to help develop these activities, perhaps drawing from things other teachers had already developed.

Another teacher commented that the Operation Physics workshop did provide materials for follow-up:

He's very excited about his topic and so he passes that enthusiasm on to his teachers. So that something you learned in physics in high school that just seemed like a mundane law of physics and not very exciting, he can make it come alive and make it very exciting, so that all of the sudden you see the wonder and the excitement of how this happens in nature. And you see that it's a common everyday thing that happens every day and yet it's also very unique and wonderful and spectacular. So I liked that.

I also like the fact that his program is very geared for a teacher with a low budget. So all the things that he does, all the hands-on things he shows you how to do, he does with very simple, inexpensive, easily available materials. Because it's hard for a teacher to have the time to go out and collect all these things.

Too many times, teachers, I think, don't try to do hands-on science because the commercially available things are too expensive and there's no budget for them.

More depth. An intriguing finding was that nearly every teacher asked for more time for the workshop activities and more depth. On the workshop response forms, there was one "low point" comment about the ideas being too complex. Other than that, the only "negative" comments elicited were that teachers wanted more. For example, "Too short. Would have been great if it could have lasted +1 hr. (or more) and go into more detail on quark investigations."

For the Physics Van, teachers wanted to see more on how scientists know about the phenomena presented. They asked to go beyond seeing the nifty effects to talk about what led scientists to develop the theory behind it. They wanted more on how scientific methods led to specific discoveries. They also felt that the reasons behind some demonstrations seemed obscure, e.g., why does the drum produce smoke rings? We see this as an exciting result that validates a basic premise of the Physics Van: By presenting intrinsically interesting phenomena, people will begin to ask more questions: Why did that happen? How does it work? How did you (or someone else) figure this out? What else can we do? And, what does it all mean?

Ironically, the physicists who presented had deliberately minimized theory assuming it would not be popular with teachers and children. But some teachers felt that more depth would have been valuable to them. This may represent an excellent example of the principle that rich, engaging experiences can build the desire for learning as well as

provide the basis for further inquiry.

Management concerns. Several concerns or recommendations revolved around student management issues. For example, one teacher from a very large elementary school said that presenting the Physics Van to the entire school makes it difficult for all children to see what is happening. Safety issues were another concern. Some teachers worried that children might conclude that electricity is fun, and anything you might do at home with electricity is a good idea. How does working with the electricity produced by a flashlight battery differ from working with that from a home AC outlet? Another teacher wondered whether her large metal jewelry posed a safety hazard with the Van de Graaff generator. Of course, these safety concerns could be an opportunity for further learning.

Conclusion

The Physics Outreach Program is an excellent example of the value of linking scientists and educators. It clearly provides a number of both anticipated and unanticipated benefits to teachers and students. In its most successful forms, it appears to extend the classroom by providing additional resources and in new things to be curious about. As one interviewee said about the Operation Physics session,

It's really nice to be able to have materials that are geared for the lower grade levels, rather than having to reinvent the wheel every time. He had some really fun ideas and fun things that I didn't think could be done.

Outreach programs such as this one definitely contribute to classroom science teaching, especially when what happens in the program can be integrated with on-going classroom learning.

Web References

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[University of Illinois Physics Van](#)

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