


ABSOLUTE ZERO

Science Educator's Guide

A Resource for
Informal and Formal Educators
of Middle School Students

About the Guide

The ***Absolute Zero Science Educator's Guide*** is meant for both informal and formal educators of middle school students and is a companion to the *Absolute Zero Community Education Outreach Guide*. Written in collaboration with low-temperature physicists and classroom teachers, the guide offers suggestions on how best to engage students in science and low-temperature physics, providing information on how to lead a classroom discussion, increase group participation, teach the process of scientific inquiry and encourage students to continue studying the science topic at hand. Copies of this guide can be downloaded at www.absolutezerocampaign.org/ask_experts/pro_science_guide.pdf.

Absolute Zero Community Education Outreach Guide

Drawing from the history of the human quest to explore the cold, the *Absolute Zero Community Education Outreach Guide* focuses on topics — from historical attempts to understand the physics of heat to modern day magnetically levitating trains — that are covered in the two-part public broadcasting special, *Absolute Zero*. The guide provides a variety of low-temperature demonstrations and experiments that are meant to inspire the next generation of scientists, describing modern research while incorporating the national science standards. It is available at www.absolutezerocampaign.org/get_involved/community_edu_guide.pdf.

Absolute Zero

The *Absolute Zero* documentaries, produced by Meridian Productions and Windfall Films, demonstrate how civilization has been profoundly affected by the mastery of cold. The programs are a unique blend of science, cultural history and adventure story. They explore key concepts, significant individuals and events in the field of low-temperature physics to show the enormous impact that the mastery of cold has had on society through such technologies as air conditioning, refrigeration and liquefied gases.

Absolute Zero is underwritten by the National Science Foundation and the Alfred P. Sloan Foundation and is based largely on Tom Shachtman's acclaimed book, *Absolute Zero and the Conquest of Cold*. The documentaries feature the struggles of philosophers, scientists and engineers over four centuries as they attempted to understand the nature of cold, to explore its deepest reaches, to create the "cold technologies" that have transformed society and to seek a deeper understanding of matter itself.

Absolutezerocampaign.org

The *Absolute Zero* Campaign Web site (www.absolutezerocampaign.org) is a place where students, teachers, parents and others interested in low-temperature physics can learn more about this unique scientific field. Teachers can download exciting classroom ideas and students can find out about some very "cool" things.

The site includes PDF files of both *Absolute Zero* guides as well as additional educational resources including graphics, biographies of historical figures, games, and a time line of low-temperature physics history.

National Partnership Program

National Partners serve as an essential building block for the outreach campaign and provide strategic guidance, support and in-kind institutional resources.

NATIONAL PARTNERS

Acoustical Society of America

American Association of Physics Teachers

American Institute of Physics

American Physical Society

American Society of Heating, Refrigerating and Air-Conditioning Engineers

Association of Science-Technology Centers

Cryogenic Society of America

Department of Energy, Office of Science

National Alliance of State Science and Mathematics Coalitions

Optical Society of America

Sigma Pi Sigma

Society of Physics Students

USA TODAY Education

NATIONAL PARTICIPANTS

National Institute of Standards and Technology

National Science Teachers Association

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Any opinions, findings, and conclusions or recommendations expressed in this guide are those of the authors and do not necessarily reflect the views of the Foundation.

Introduction

The *Absolute Zero* educational outreach program was born from the conviction that 21st century science and technology must be integrated into science education. More and more, educators are being asked to teach about current scientific developments and how they impact the daily lives of young people. Low-temperature physics is a perfect vehicle for this kind of science education.

The study of cold has transformed society in the last 100 years with such seemingly simple things as refrigeration and air conditioning. More recently, the quest for extremely cold temperatures has been the source of some of the most interesting modern physics research, earning Nobel Prizes for nine researchers in the last decade. Low-temperature science has affected everything from how oxygen is stored in hospitals, to how rockets lift off, to how super-fast trains travel.

In addition to its relevance to the modern world, low-temperature physics serves as an excellent backdrop to explain fundamental concepts about how atoms behave; what causes temperature change; the differences between liquids, solids and gases; and other basic science that is regularly taught in middle school.

Two *Absolute Zero* guides have been designed to help middle-school educators introduce low-temperature science to their students. The *Absolute Zero Community Education Outreach Guide* provides detailed modules on such subjects as temperature, thermodynamics, how animals survive the cold, and the race to reach the coldest temperature in the world. It is appropriate for new and veteran educators alike. Each module in the guide includes:

- ✓ experiments and demonstrations
- ✓ talking points for the instructor, with scientific explanations and historical facts
- ✓ pointed questions to get the group talking
- ✓ safety guidelines
- ✓ optional research projects for the students

The *Absolute Zero Science Educator's Guide* serves as a companion to the first guide, providing a road map for lively and informative science presentations. This guide emphasizes teaching science inquiry as well as science fact. It is aimed at both middle-school teachers and those engaged in informal education. It is also meant to encourage non-professional teachers, such as scientists and engineers, to help young people learn about the exciting world of low-temperature physics.

CONTENTS

Skills and Tips

A successful science educator should have the following skill sets:

- ✓ the ability to teach scientific process and inquiry as well as science fact
- ✓ thorough knowledge of the subject
- ✓ confidence in leading a group setting

The *Absolute Zero Science Educator's Guide* suggests a number of ways to strengthen these skills. It works within the National Science Standards, reviews relevant safety rules and provides additional Web-based resources. In short, it is designed to help successfully translate your passion for science to the next generation.

Science Inquiry: Teaching More than Facts

Over the last few decades, educators have pushed science education in a new direction. Instead of having students simply memorize facts, teachers also focus on the process of science investigation. It is not enough for students to be able to recite information about the universe. They need to understand how that information was discovered and to learn methods that will lead to future discoveries. In essence, this educational technique teaches students how to be a scientist. Hopefully, this will encourage more budding scientists and engineers to enter today's competitive global marketplace. Even for those who do not choose a scientific career, learning the methods of science means learning how to problem-solve, which is a crucial life skill.

Helping Students Make Their Own Inquiries

To be an effective teacher of scientific inquiry, it may be useful to think of yourself as an "organizer" of the classroom discussion rather than as a lecturer. The teacher-as-organizer provides opportunities to discuss facts and investigate phenomena. An organizer asks questions and encourages the students to draw their own conclusions.

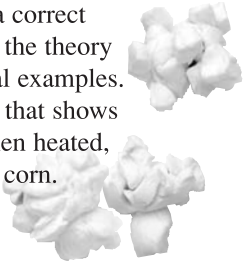
A presentation might proceed in the following order:

ESTABLISH WHAT THE STUDENTS KNOW: Ask initial questions to determine what the group does and doesn't know about a subject. In the case of the *Community Education Outreach Guide* module "States of Matter," for example, the first set of questions has students brainstorm on the differences between solid ice and liquid water.

INVESTIGATE: Set up an experiment or demonstration to explore the topic. Actively engage students in performing the experiment and encourage them to predict outcomes. In the "States of Matter" module, the first set of experiments tests the density, volume, shape and compressibility of solids, liquids and gases.

DISCUSS THE RESULTS: Ask students to present their results and then theorize about what they observed. Help guide the conversation towards the correct theory. In "States of Matter," students are encouraged to understand that each of the properties they investigated depends on the material's atomic structure.

EMPHASIZE THE THEORY: Once the group has moved toward a correct understanding, it is time to iron out any misconceptions. Reiterate the theory behind the phenomena the students observed and provide additional examples. The "States of Matter" module ends with a popcorn demonstration that shows students how the liquid inside a popcorn kernel turns into a gas when heated, thus expanding and making the kernel explode — and popping the corn.



What Do You Think?

As you can see from the outline, experiments and demonstrations are important parts of the educator's toolbox, but asking thought-provoking questions is equally crucial.

- In general, questions should be open-ended. Avoid yes or no questions and leading questions. "What is different between a liquid and a solid?" for example, instead of "Do you think solids are denser than liquids?"
- Be prepared to ask the question in several different ways. Refine the questions if students seem confused.
- Ask questions in a logical order.
- A thoughtful follow-up question will encourage students to expand upon their original answer.

- Timing is important. Don't rush students if they need a moment or two to gather their thoughts and don't jump in with an instant response. Take a tip from successful interviewers: a deliberate silence will often encourage students to expand on an initial comment.
- Try not to immediately correct any misconceptions. Instead, ask more questions or perhaps suggest an experiment or thought experiment that will help them figure it out for themselves.
- If time is an issue, or the group is especially large, it may be unreasonable to call on individual students for an answer. In this case, you can call out a question to the group at large. Let them mull it over for a moment, and then provide the correct answer yourself. This keeps the presentation moving, but still gets them thinking.

Tales from the Trenches:

Working with a Crowd

A demonstrator who works mostly with auditorium-sized groups calls out questions to the crowd. He encourages them not to raise their hand cautiously but to yell out the answer. That way, not only does everyone remain focused despite the group's size, but also if he doesn't necessarily hear the right answer it doesn't slow down the flow. He simply says: "I heard the answer over there. . ." and begins to explain the correct answer.

Asking questions and providing experiments aside, a teacher often needs to step in to give explanations. There is no reason to let a group fumble down the wrong path for too long, as this just causes unnecessary frustration. Experienced educators say that sometimes one simply needs to take the floor and explain a subject to really help the students grasp it.

Science and Society

There is another new emphasis in science education: teaching the effects of science on society, including how it applies to health, technology and policy. Scientists understand that their work must find its context in society, which means that even those who don't follow careers in science need to understand science's impact and be ready to make decisions about how to use it. Consequently, young people should be encouraged to learn how science impacts humans and vice versa.

Much like teaching scientific inquiry, incorporating societal context will help students think for themselves and make critical analyses. For example, ask students how specific research has touched their lives. Reference recent news articles. Have them research the scientists currently working in the fields you're studying — better yet, invite one to the classroom for the day! With more mature students, don't shy away from controversy. Encourage them to brainstorm about the most creative, most useful and most ethical ways to use scientific applications.

For example, in the "Refrigeration" module of the *Community Education Outreach Guide*, societal context is introduced in a variety of ways. Students are asked to brainstorm on what life would be like without a refrigerator. You can invite a refrigerator repairman to class — or perhaps invite a doctor, a grocer, or a farmer to describe how refrigerators and freezers are used in their work. Lastly, you might discuss how refrigerants have been changed over time due to their effect on the environment.

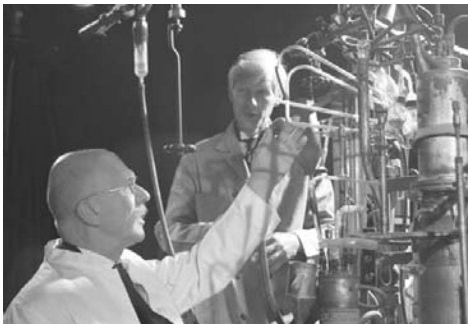
Tales from the Trenches:

Don't Shy Away from the Tough Subjects

One demonstrator worked with a school to put together a student experiment for the Space Shuttle Columbia. For three years the demonstrator was a liaison to the astronauts, training them on the particular student experiment. The shuttle went up, and the demonstrator came to the school to tell the students their experiment was finally flying and that they should all turn on their TVs over the weekend to watch the shuttle — and their experiment — land. It was, of course, the day Columbia broke apart in 2003. "That was the second hardest day of my life," says the demonstrator.

"The hardest was the next day," he said. He went back to the school to speak to 500 students about life and death, risk and benefits, and why science and technology keep pushing forward even after a failure.

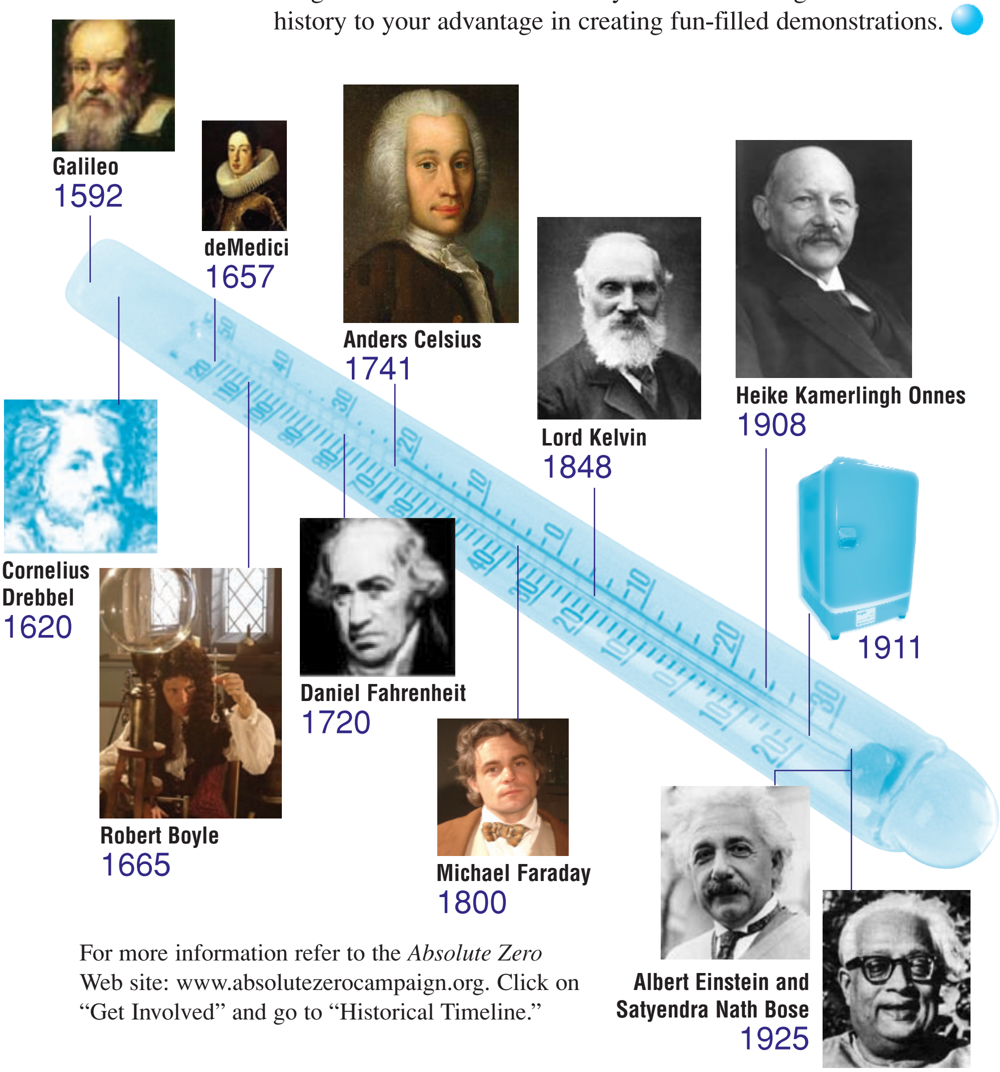
History of Science



Teaching the history of science is another way to place science firmly in a human context. It is also a great way to engage students. When you discuss the historical time line of key scientific discoveries, you drive home the point that science is a process of problem solving — and not always a linear one. You also provide interesting stories that will help the students remember the theories.

The *Community Education Outreach Guide* includes many of the key scientists involved in the study of low-temperature physics for the past 400 years. For example, the "Superconductivity" module describes the history of how Lord Kelvin and Heike Kamerlingh Onnes had different hypotheses about what happened to electrical current as it ran through extremely cold metal. Kamerlingh Onnes performed an experiment to differentiate between the two theories. Once the metal was cold enough, electrical current flowed through it without any resistance at all — which corresponded with his original prediction. Kamerlingh Onnes named the state superconductivity. The tale highlights the classic hypothesis-experiment-conclusion process that is integral to the scientific method. (And interestingly, his theory about why superconductivity occurs was completely wrong, demonstrating that even respected scientists make predictions, test them, and sometimes find they are wrong.)

All of science is filled with such stories, and the tales are often peopled with fascinating and sometimes wonderfully cantankerous figures. Use science history to your advantage in creating fun-filled demonstrations.



For more information refer to the *Absolute Zero* Web site: www.absolutezerocampaign.org. Click on "Get Involved" and go to "Historical Timeline."

National Science Education Standards

In 1996, the National Committee on Science Education Standards and Assessment of the National Research Council developed a set of National Science Education Standards for elementary, middle school, and high school students. Teaching scientific inquiry, the history of science, and science's role in society are key parts to those standards.

Quoting directly from the Standards:

The new vision includes the "processes of science" and requires that students combine processes and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science. Engaging students in inquiry helps students develop:

- *Understanding of scientific concepts.*
- *An appreciation of "how we know" what we know in science.*
- *Understanding of the nature of science.*
- *Skills necessary to become independent inquirers about the natural world.*
- *The dispositions to use the skills, abilities, and attitudes associated with science.*

NATIONAL SCIENCE EDUCATION STANDARDS

	Levels K-4	Levels 5-8	Levels 9-12
Science as Inquiry Standards	Abilities necessary to do scientific inquiry Understanding about scientific inquiry		
Physical Science Standards	Properties of objects and materials Position and motion of objects Light, heat, electricity, and magnetism	Properties and changes of properties in matter Motions and forces Transfer of energy	Structure of atoms Structure and properties of matter Chemical reactions Motions and forces Conservation of energy and increase in disorder Interactions of energy and matter
Science and Technology Standards	Abilities to distinguish between natural objects and objects made by humans Abilities of technological design Understanding about science and technology	Abilities of technological design Understanding about science and technology	
Science in Personal and Social Perspectives	Personal health Characteristics and changes in populations Types of resources Changes in environments Science and technology in local challenges	Personal health Populations, resources and environments Natural hazards Risks and benefits Science and technology in society	Personal and community health Population growth Natural resources Environmental quality Natural and human-induced hazards Science and technology in local, national, and global challenges
History and Nature of Science Standards	Science as a human endeavor	Science as a human endeavor Nature of science History of science	Science as a human endeavor Nature of scientific knowledge Historical perspectives

Talking the Talk

Successful educators must be more than just knowledgeable. They must engage their audience and keep them focused. This skill improves naturally through sheer practice, but remembering a few simple guidelines will help immeasurably: be confident and flexible, and maintain a good sense of humor.

Adjusting Your Talk on the Fly

Things will inevitably go awry — whether it's a failed experiment, students with a different knowledge base than expected, or a power outage — and you need to have the ability to change your lesson plan if necessary. You may be surprised either by how much young people know about a subject or what they don't. Be prepared to adjust your presentations to your group's level of knowledge and interest. Skip over unnecessary explanations and expand on crucial ones.

Also be prepared to explain the mundane. Embrace some of the fun questions from students. For example, the number one question young people ask space experts is "How do astronauts go to the bathroom in the space shuttle?" Try to adjust your talk to incorporate their questions as much as possible.

Simplify Your Explanations

A disadvantage to knowing a subject well is that it can be hard to remember how to describe it simply enough for the uninitiated. As you explain a new theory, be extra vigilant to not use advanced vocabulary, to refrain from describing all the exceptions to every rule, and to avoid mentioning every single fact.

There is a time and place for precise details, but even college-level physics courses teach a simpler, "incorrect" version of physics — Newtonian mechanics — before tackling the more accurate Theory of Relativity. Simple explanations, even if incomplete, are better than accurate ones that are not understood. A great way to remind yourself about the correct level of detail is to read age-appropriate books on the subject. Also, make sure to continually monitor your audience to see if students are absorbing the information.

Tales from the Trenches:

Simplifying An Explanation

One science demonstrator repeatedly tells his audience that since temperature depends on how fast the atoms in a substance are moving, the coldest temperature — absolute zero — occurs when atoms stop moving altogether. "That description," he acknowledges, "is out and out wrong, since quantum mechanics says an atom could never be perfectly still." But he continues to use his explanation since it's an effective way to explain temperature and energy, and he knows the students can learn the details of quantum mechanics later in life.

Occasionally a quick student has called him out — and he simply admits the student is right. He explains that what he said is true (ignoring quantum mechanics) and accurate enough for the demonstration and talk he is giving at the time.

Keep Them Participating

The best way to keep a group focused is to encourage their participation. Different techniques work better with groups of different sizes. Here are several suggestions for keeping everyone involved:

- Show-and-tell is the most basic way to keep students' attention. Interesting demonstrations and experiments help cement a scientific theory while capturing the imagination. In the absence of experiments, download images off the Internet and pass them around to the group.
- Taking a break to set up a demonstration can derail the group's concentration. Make sure everything is prepared in advance. To easily remember the sequence of your talk, place the items for your presentations in order on a table.

- With a small group, invite the students to participate in an experiment where safety concerns allow. You may divide them into separate groups, or simply have them congregate around you while you perform the experiment. If students cannot conduct an experiment themselves, invite volunteers to help you with the presentation.
- Encourage students to speak up when they have questions. In a smaller group, you can usually let them call out questions. With a larger group you may give students 10 minutes for questions at the end or have them provide you with written questions for the next session.
- Have students write down their predictions before conducting an experiment and afterwards, their theories about what they observed.
- Give students a mini-assignment in advance. Suggest they bring in a relevant newspaper article or ask them to explore additional science, current technologies, or historical scientific figures relating to a given subject. (One of the *Community Education Outreach Guide* modules asks students to bring in an ice cube — without giving them guidelines on how to do so. Discussing what each student did and whether it worked is a great way to start a conversation on states of matter and how they depend on temperature.)

Reaching Everyone

Keep an eye out for those who are less inclined to become involved in the discussion. They will differ in every group — it's not always just the shy students. Watch for students who are making eye contact or getting slightly antsy in their chairs — these may be signs the student is ready to speak if you offer encouragement. After one person states an idea, ask the rest of the group for their opinion. Quieter students will sometimes respond to a peer's statement better than to a teacher. Whether it's a shy student or the class clown, that student could be invited to serve as a volunteer.

If you are not getting sufficient responses from the group, here are two proven techniques. Ask a question, give everyone a few moments to think, and then pick a name out of a hat. Or, ask a question, have everyone quickly write down their thoughts — taking just 10 seconds or so — and then discuss with their neighbors. After a minute, have a member of each mini group present ideas to the room.

If students begin talking to one another, try talking more softly — it will force the students to be quiet and strain to hear. (Once you have their attention, speak up again!) Move around the room as you talk, walking up and down the aisles, making eye contact throughout the session.

Getting Feedback

Unfortunately, asking students if they understand a topic rarely nets an accurate answer. For a better assessment, pick one or two students to explain in their own words what you've just discussed. Go over the material again if necessary.

If you work repeatedly with the same group of students, you may assign a different person to be a reporter each day. That person will take notes that can be copied and handed out to everyone at the beginning of the next session. Misunderstandings or confusion on the part of the reporter will often be the same with the rest of the group. This will allow you to explain the subject again.

Safety

Every institution — especially a school — has detailed safety rules. If you are an informal educator, you may be surprised at how strict these safety rules can be. Many scientists have fond memories of playing with what they considered relatively "harmless" liquid nitrogen when they were younger. However, concerns about this and many other materials are real and must be accommodated.

If you're presenting a demonstration at a school, check in advance with the class-room teachers or principal. At a museum or science center, check with the outreach director. Describe the items you will be using in your experiments. Educators will recommend what is appropriate to the particular age group. A well-behaved, mature group may be able to handle some things — boiling water, for example — that would not be acceptable with a young audience.

Here are a few important safety concerns:

- Many objects such as mercury thermometers are not allowed in schools. Many materials — such as liquid nitrogen and rubbing alcohol — may only be stored at a school if a Material Safety Data Sheet has been filled out warning employees of the potential occupational hazard.
- Several modules in the *Community Education Outreach Guide* suggest using liquid nitrogen for experiments. **But it should only be used if you are very experienced using it.** While liquid nitrogen is not dangerous if handled correctly, it is only appropriate for a mature, well-behaved group and only adults should handle it. You must have the requisite safety equipment. Wear goggles. Use thick leather or nylon-coated fabric gloves at all times and be extra careful not to get any inside the gloves as liquid nitrogen trapped against your skin can burn you. Do not spill it on your body. Liquid nitrogen will normally evaporate and do no harm, but it will burn you if it gets trapped against your skin. Don't store it on site at a school or where children can access it. Liquid nitrogen must be used in a spacious, well-ventilated room. You can learn more about liquid nitrogen safety rules by visiting: http://webs.wichita.edu/facsme/nitro/safe.htm.
- Control the students' exposure to extremely hot or extremely cold materials.
- Many schools do not allow eating in science labs. If you would like to conduct a demonstration that involves cooking or food — such as several suggested in the *Community Education Outreach Guide* — you would need to do so in a kitchen setting.

Tales from the Trenches:

The Principal Knows Best

One experienced demonstrator was informed by the principal of a school that liquid nitrogen wasn't allowed into the building since it was a "pollutant" that would contaminate the air when it evaporated. Explaining that air already was 78 percent nitrogen served no purpose and the principal was adamant.

Administrators are occasionally overly cautious and you should certainly try to correct misinformation when you can — but ultimately they get to make the safety rules and it's your job to find out what those rules are ahead of time!

Especially for New Educators: Advance Work

Some teachers seem to have been born with charismatic personalities and unique knowledge of children's brains, but they too endured trials by fire. As with any successful endeavor, practice is key. Award-winning teachers say that one of the most important factors in their success was working with veteran colleagues. Seek teachers you admire and ask them for their suggestions. Better yet, try sitting in on their classroom demonstrations.

Tales from the Trenches:

Focusing on a Single Message

A Nobel Laureate who frequently speaks to elementary and middle-school children says he has chosen over the years to focus on a single message: simply through his manner of presentation, he portrays that science is fun and scientists have fun doing what they're doing. He emphasizes this more than teaching specific facts. "They're not going to fail to learn something new," he says, "but that's not my point. My key message is just that science is not some boring thing, delivered by dry lectures." He has picked one concept, and every aspect of his talk is directed at showing how exciting science can be. With that kind of concentration, he usually succeeds.

Designing a Presentation

Create a presentation that is best suited to your own style and expertise. Tailor your presentation to your knowledge, strengths and interests.

- Some demonstrators thrive on complex computer presentations, while others want nothing more than a chalkboard. What works best for you? Computers? Slides? Articles? Experiments? Videos?
- Choose a subject that intrigues you — one that will demonstrate your passion for science. With the *Community Education Outreach Guide* modules, pick the ones that resonate with you.
- Set attainable goals. What do you want to accomplish? What information do you want students to remember? Instead of a scientific theory, it may be the importance of critical thinking or inspiring students about the challenges of a career in science.
- Don't overwhelm your audience. Remember, most people cannot remember more than two or three pieces of new information at a time.

Stay Current

Even if you have taught the subject for some time, or are a professional in a particular field, you should always review the latest information prior to the presentation. Log on to the Web. Look for any recent announcements or scientific breakthroughs that may be of interest to this age group. Providing current information will help establish credibility with your students.

The *Community Education Outreach Guide* provides detailed teaching modules and basic scientific information. In addition, the Internet overflows with science primers, teaching guides and demonstration suggestions. (At the end of this guide are additional Web-based resources.)

Tales from the Trenches:

Talking About Yourself

A space science demonstrator begins every talk with a photo of himself at age four standing at Cape Canaveral — the very day he decided he would be a rocket scientist. Then he flips to the next slide, a photo of himself as an adult watching his first experiment being placed on the space shuttle. "You never know when that magic moment is going to happen," he says, "when you're going to inspire someone to seek out a different interest or a career path or just get someone revved up." He incorporates all sorts of personal stories to help provide those "magic moments."

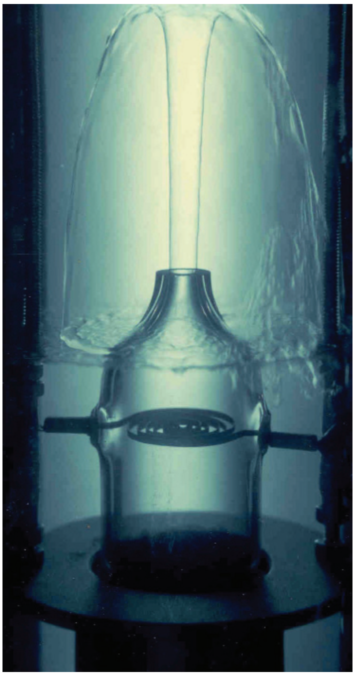
Talking About Yourself

Whenever possible, incorporate personal stories in a presentation. This will attract students' attention as nothing else can. For example, how did you become interested in this subject? What do you do in your professional life? What have been some of your biggest challenges? What were the toughest subjects for you to understand? How does physics impact your life?

Unfortunately, some adults are not inclined to incorporate "personal" tales in what they believe should be an objective, fact-based field. However, experience shows that students are more inclined to get interested, and to remember information, if they can relate it to a particular story. And, when you are talking about a subject you know so well, you are more often perceived as informed, confident and intriguing to your audience.

Practice

The last form of advance work may seem obvious, but it is too critical not to mention: practice your presentation ahead of time. Write an outline — or notes or cue cards. Make sure you have all the necessary materials and that your demonstrations will work. Rehearse your pacing. Knowing your subject is the first step, but you need to know your presentation well, too.



Especially for New Educators: Seeking Speaking Opportunities

We hope this guide will encourage science professionals to volunteer at schools, science centers, museums and after-school programs. A number of national organizations support the educational outreach program on behalf of *Absolute Zero* — indeed, you may have received this booklet because you belong to one of these organizations. As you would expect, they are an excellent resource for potential speaking engagements. (The inside cover of this guide provides a complete list of National Partners and Participants.)

There are literally hundreds of potential speaking forums in every community. Schools, science centers, libraries and after-school programs are the most obvious places. They will be receptive to individuals who can provide informative, useful and motivational presentations. Making contacts at these institutions should be relatively easy. Most schools have career days, science fairs or assemblies, while others may be willing to invite guests into their science classes.

You may also want to reach out to the local chapters of the Boys & Girls Clubs, the Boy Scouts of America, the Girl Scouts of America, 4-H Aerospace, PBS stations, etc. Think about any local organization that regularly holds activities for children including libraries, the YMCA or your house of worship. In fact, your own workplace may well have a public outreach program. If it doesn't, think about starting one.

In Conclusion… Get Started!

The *Absolute Zero* documentaries should generate considerable interest in the subject of low-temperature physics. While watching the shows isn't a prerequisite to teaching one of the *Absolute Zero* modules, the documentaries will be helpful in capturing the attention of young people. Whether you're a teacher or an informal educator, we encourage you to capitalize on these two unique programs.

Whatever your background, sharing your passion for science is one of the best ways to inspire the next generation. We hope this guide will help you with this essential work.

ADDITIONAL RESOURCES

General Resources

Absolute Zero Campaign Web Site: http://www.absolutezerocampaign.org

National Science Standards: http://www.nap.edu/readingroom/books/nses/html/6a.html

State Science Standards: http://www.caosclub.org/totalcaos/members/statestandards.html

Education in Museum and Technology Centers: http://www.astc.org/resource/education/index.htm

USA Today Education: http://www.usatoday.com/educate/home.htm?Loc=vanity

National Science Teachers Association: http://www.nsta.org/

Department of Energy, Office of Science, Workforce Development for Teachers and Scientists: http://www.science.doe.gov/Program_Offices/Workforce_Development.htm

General Teaching Tips

McMaster University Centre for Leadership in Learning: http://www.mcmaster.ca/cll/resources/teaching.tips/index.htm

Honolulu Community College Faculty Development Teaching Tips: http://honolulu.hawaii.edu/intranet/committees/FacDevCom/guidebk/teachtip/teachtip.htm

How to Encourage Discovery Learning: http://trc.virginia.edu/Publications/Teaching_Concerns/Spring_1994/TC_Spring_1994_Teaching_Tips.htm

Questioning Techniques: http://www.teachingtips.com/articles/Mtechniques1.html

Attention-Getting Tips: http://www.atozteacherstuff.com/Tips/Attention_Getters/index.shtml

Science Lesson Plan Ideas

Society of Physics Students, The Wormhole: Physics Problems, Trivia, Humor, Games: http://www.aip.org/education/sps/wormhole/wormhole.htm

Science and Art Teaching Tips: http://www.hometrainingtools.com/articles/science-and-art-science-teaching-tip.html

Physics Lesson Plans for Elementary and Middle School: http://www.physics.rutgers.edu/hex/visit/lesson/lesson_links1.html

American Chemical Society, Activities on Matter and Its Changes: http://www.chemistry.org/portal/a/c/s/1/acsdisplay.html?DOC=education%5Cwande%5Cresourcechem%5Cmatter%5Cmatter.html

Exploratorium Demonstrations on Heat and Cold: http://www.exploratorium.edu/snacks/iconheat.html

Kitchen Chemistry: http://www.chatham.edu/pti/Kitchen_Chem/abstract_page.htm

Department of Energy's Jefferson Lab Teacher Resources: http://education.jlab.org/indexpages/teachers.html

Girls Go Tech: http://www.girlsgotech.org/girlsgotech_booklet.pdf

Newton's Apple Teaching Guides: http://www.ktca.org/newtons/alpha.html

The American Association of Physics Teachers, The Physics Teacher: http://scitation.aip.org/tpt/

American Physical Society, Physics Central: http://www.physicscentral.com/

Low-Temperature Science Posters: http://www.ph.rhul.ac.uk/lowtemp/posters/

The History of the Refrigerator and Freezers: http://inventors.about.com/library/inventors/blrefrigerator.htm

The Origins of Home Refrigerators Lesson Plan: http://66.46.139.215/proj_01/vmcp/docs/chill_lesson2.pdf

American Society of Heating, Refrigerating and Air-Conditioning Engineers Cool Science Kit: http://www.ashrae.org/content/ASHRAE/ASHRAE/ArticleAltFormat/200411151367_347.pdf

Science Activities and Tips: http://taledo.tripod.com/Science/

PBS Science Curricula: http://www.pbs.org/teachersource/sci_tech.htm

Home Science Tools: http://www.hometrainingtools.com/articles/acat_science-links.html

National Science Teacher's Association Teacher's Grab Bag: http://www.nsta.org/resourcesgrabbag

For the Informal Educator:

RE-SEED: Retirees Enhancing Science Education through Experiments and Demonstrations: http://www.reseed.neu.edu/

For the Professional Educator:

National Science Teachers Association Gateway for Professional Development: http://institute.nsta.org/

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