Scientist in the Classroom: Highlights of a Plasma Outreach Program

A. Nagy, Princeton Plasma Physics Laboratory, C.A. Danielson, R.L. Lee, J. Valentine, P. Winter, General Atomics

The General Atomics Education Program "Scientist in the Classroom"

Brings scientists, engineers and students together to interactively discuss plasma physics with students in the classroom. A major program goal is to make science an enjoyable experience while showing students how plasma physics plays an important role in their world. An overview on fusion, energy, and the environment is presented to students early in the session. Using hands-on equipment, students manipulate a plasma's characteristics using magnetic fields, and observe its spectral properties; as well as observe physical properties of liquid nitrogen, infrared waves, and radioactive particles. One of the benefits of this program, relative to facility tours, is that it optimizes cost and scheduling between the scientific staff and students. This program and its equipment are receiving accolades as an adjunct teaching option available to Southern California schools. Student exit interviews reflect strong positive comments regarding their hands-on learning experience and science appreciation.

*Supported by U.S. DOE Grant DE-FG03-97ER54402 General Atomics, and DE-AC02-76CH-03073 Princeton Plasma Physics Laboratory

GENERAL ATOMICS

PPPL PRINCETON PLASMA PHYSICS LABORATORY

General Atomics–
Scientist in the Classroom

Introduction

- Scientist in the Classroom is a General Atomics Education program that brings a scientist and plasma physics demonstration equipment to the classroom to give students a hands-on experience of plasma and some of its characteristics. The program allows physicists, engineers, and technicians to share their experience and knowledge with students during a classroom visit. The topics presented are related to plasma physics and fusion technology and include discussion of fusion energy research, status, environmental issues, magnetism and electricity,...and more.

Fusion Science and Technology Topics Presented in the Classroom:

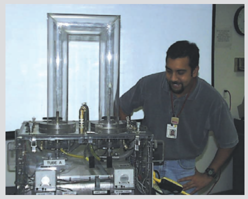
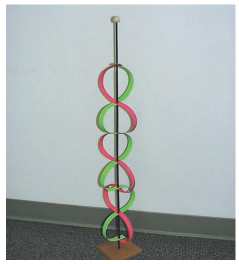
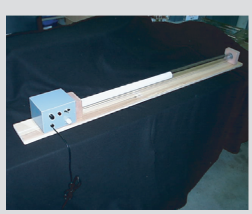
Different levels of the following topical areas are presented to students in Grades 3-12

- Definition of fusion/plasma
- Presentation on plasma applications and fusion reseach
- Environmental aspects of fusion energy production
- Global warming effects of fossil fuel use
- Benefits of fusion-compared and contrasted to fossil fuels, and other energy sources
- Projected energy resource availability, and how fusion fits into humanity's future
- Engineering challenges associated with a fusion device are reviewed, i.e. vacuum chamber design, magnetic coil function, machine support structure, and heat transfer thermal considerations
- Several plasma diagnostic techniques are discussed, i.e. density, current, position, composition, and temperature measurements

Science Topics Explored are Aligned with Fundamental Education Standards

- Matter and its building blocks: proton, electron, and neutron
- Electrical charge and electrical character of materials
- Magnets and magnetic fields and their behavior and interaction with charges
- Extreme temperatures and their effects on different states of matter
- Electromagnetic spectrum from DC to X-rays
- Barometric pressure and vacuum
- Density effects on molecular mean free path in gases at various pressures
- Different forms and transformations of energy

Scientist in the Classroom–Physics Demonstration Devices

Plasma Tube		The plasma tube gives students the opportunity to experience and manipulate plasma first hand using magnets and variable gas (air) pressure.
Electromagnetic Wave Model		The E&M model shows the orthogonal relationship between electromagnetic wave components in 3D. It is adjustable along the axis to show the relationship between frequency and wavelength.
Vacuum Chamber		The vacuum chamber demonstrates barometric forces on a vacuum chamber. The compound gauge introduces new pressure units.
Infrared Camera		The infrared camera opens the student's view of the thermal world, how some materials pass infrared and not visible light and vice versa.
Degaussing Coil		The degaussing coil and permanent magnets demonstrate magnetic field interactions. This models how the magnetic field from a plasma interacts with its confining fields.
Orbitz		(A soft drink that has neutral buoyancy balls floating in a clear medium) Although quite sweet, the Orbitz soft drink is perfect for describing to students the concepts of mean free path and the relationship of gas atoms at low vacuum pressures.
Half Coated Fluorescent Tube		The half-coated fluorescent tube shows students plasma in action in their everyday world. The plasma current and voltage are measurable and variable. A grating is used, to show the difference between the spectrum from the fluorescent side and the clear side.

Scientist in the Classroom

- Program and equipment can be presented in any classroom or science lab, even a gymnasium
- Presentations can be edited for audience level in real time
- Student enthusiasm is sparked by interactive equipment not commonly found in the classroom such as infrared camera, plasma device, vacuum chambers and liquid nitrogen
- A single person can enthrall ~150 students in 5 classes in one day. In contrast, 5-6 staff members for 4 hours are typically required for a fusion facility tour
- No group transportation needed
- The program is free to the schools
- Scientists are rewarded through contact with an appreciative and captive audience
- Students can connect with a scientist in the student's environment; helping to demystify the scientist stereotype
- The program can be presented to audiences from 8 years and up, teachers also find the demonstrations exciting.

Tours, Internships, and Visiting Classroom Scientists
How do they compare?

Aspect	Scientist-in-the-classroom	Facility tour	Summer students
Material modification	On the fly	Standardized	N/A
Presentation site	At the school	Fusion facility	Fusion facility
Students reached/day	150	50	1-3
Manpower required	1	5	1
Duration student perspective	Presenters perspective 1 hour/student	4 hours/student	4-8 hours/day student
Man hours/day	6	20	4-8
Student transportation	None	Bus	Car (individual)
Monetary costs to school	None	None	Student stipend
Pre-program requirements	None	Teachers show videotape, do some part of notebook	None

The National Science Education Standards are stressed:

- The basis for the presentation uses the standards, listed below, as the approach to giving students opportunities to ask basic questions, observe natural phenomenon and discuss obsevations.
- The program requires the students to ask and attempt to answer original questions
  - Student's curiosity is sparked by providing a hands-on experience outside of the student's normal experience
- Provides opportunities to conduct true inquiry-based experimentation
  - Student's are allowed to manipulate touch, measure, see, hear physics demos with little explanation and their questions are formulated and posed during this time
- Integrates the natural sciences
  - Student's are led into discovering plasma and the electromagnetic spectrum in the world around them
- Articulates the natural sciences across grade levels
  - Aspects of fusion such as subatomic particles are discussed in very simple terms in the lower grades and more specific details are presented to students in the higher grades

- The topics presented build on previous learning
    - There is a joint teacher/scientist team effort in presenting the electromagnetic spectrum, or subatomic theory
- Stresses understanding and application rather than rote memorization
    - The presentation is about plasma science and fusion as a viable and long-term energy source. The reasons for attaining fusion as a long-term energy source compared to other energy resources, their pros and cons, as well as future supplies are discussed
    - Plasma applications are illuminated, e.g. IC chip production, television picture screens, fluorescent lights, and material manufacturing processes to name a few
    - Hands-on approaches to learning give students a full experience; physical, visual, audible, and emotional, to enrich their understanding of the world around them

Content Standards
Grades K-4

Properties of objects and materials

- Basic properties of the states of matter are shown. Plasma is the focus with a live demonstration being very interesting to students

Position and motion of objects

- Students witness the production of plasma between the electrodes and its control and movement using hand held permanent magnets

Light, heat, electricity, and magnetism

- Plasma is about all of these topics. Strong permanent magnets, electromagnets, an infrared camera, and liquid nitrogen challenge the students to observe physical properties of materials in different ways

Content Standards
Grades 5-8

Properties and changes of properties in matter

- Plasma production using air and other gases show the transition from a neutral gas to an ionized gas
- Liquid nitrogen clearly demonstrates the liquid to gas transition, as well as the gas to liquid transition of oxygen condensing in a balloon
- A half coated fluorescent tube has all the states of matter solid walls, liquid mercury droplets which vaporize, and Argon gas which ionizes

Motions and forces

- Magnetic force effects on ionized particles, other magnetic fields, and magnetic metals are explored
- The simple boiling of liquid nitrogen, having the downward column of condensed vapor catches student's attention and opens the door to understanding the effects of heat, or in this case the absence of heat
- The shrinking of inflated balloons placed in liquid nitrogen leads the student to learn about the internal energy changes of matter

Transformation of energy

- The conversion of electrical energy to heat, magnetic energy to kinetic energy, and heat energy to light are all inherent in the interactive items

Content Standards
Grades 9-12

Structure of the atom

- The lecture presents the structure of the atom, and how science applies the atomic theory in plasma processes
- Low level radioactive sources illuminate the structure of the atom

Structure and properties of matter

- Students observe plasma and learn how it is produced, and have a hand in changing its characteristics, e.g. density changes, positional changes, and color changes
- Liquid nitrogen and its "cold" behavior in condensing oxygen to a liquid, and significantly changing the volume of air-filled balloons clearly demonstrates the thermal properties of gases

Chemical Reactions

- Chemistry verses nuclear reactions are contrasted in the lecture section

Forces and motions

- Magnetic forces, electric field forces, and resulting plasma motions are explored directly by the students.
- Changes in the internal energy of matter are observed using liquid nitrogen effects on air filled balloons.
- Plasma oscillations in the plasma demo are observed and manipulated by changes in plasma density and magnetic field strength
- Low level radioactive sources are examined for transmittance through various materials

Interactions of energy and matter

- Phase changes based on liquid nitrogen demonstrates changes in the internal energy of matter
- The plasma demo creates ionized gas with its resultant light and kinetic motion
- The radioactive sources demonstrate energetic matter and atomic collisions
- The fusion presentation describes the method of harvesting the large energy production of a fusion reaction

Non-Content Standards

- Presenter flexibility---the age groups, and class size tend to prescribe the format. Lectures are used to present an overview of the fusion process. The lectures are longer with the higher grades, and shorter with the lower grades
- Present fusion research--- first hand science experience and research is discussed, since having a scientist in the classroom is a novel opportunity for most teachers and students
- Inquiry---is discussed with students and how it is used in the science world to discover new avenues of knowledge about the world around us
- Career Path---Students can question the scientist about their career path and job

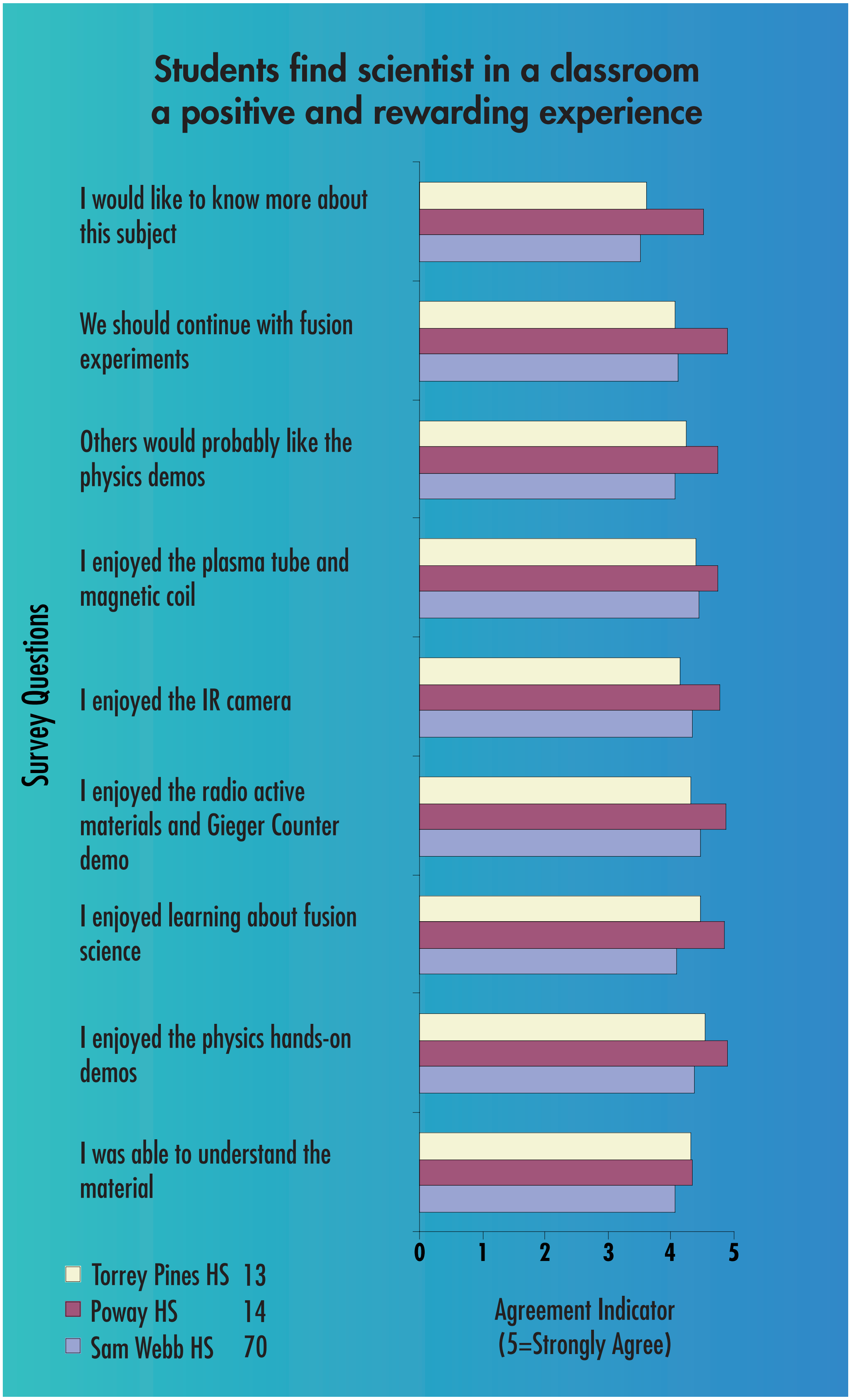
Student Exit Interview Responses

Student follow-up questionnaires are used to gain some measure of the program's effectiveness. Most of the questions ask the student to note specific portions of the overall presentation. Other questions deal with the student's future interest in fusion and plasma-related science. The questionnaires also have room for direct comment

Some often-repeated comments include:

1. I enjoyed the physics "toys"
2. Come back again and bring more "toys"
3. Take the presentation to other classes
4. The lecture was too long, demos were good
5. There could have been more explanation on the physics demos
6. Too many big words were used
7. There wasn't enough time for demos
8. Thank you for coming to our class and taking time out of your day
9. We really enjoyed your presentation

Scientist in the Classroom
Exit Interview Results



Bar Chart Interpretation

The survey questions present a positive statement regarding the student's experience of the presentation, and ask the student to agree or disagree on a scale of 0-5. The chart shows that most students agree with these statements and this is a positive comment on the student reception to the program.

A negative trend would be indicated by the averages falling below the mid-range score of three. Since all the scores are not at a score of five, the chart shows that students on average do not agree strongly with the positive statements. The data from Poway high school was from an advance physics class presentation, thus showing a strong agreement.

All of the surveys were completed after the school visits, usually the next day when they were back in the same class. This time delay helps get a better indication of what the student's felt, since they had some distance from the presenter and their teacher, through the time delay.

The presenter, reviews each school survey after the visit to receive feedback for continual presentation optimization. This has turned out to be a very useful and rewarding tool for the program.

Future Physics Demos and Program Development

Creation of more hands-on physics demos--to keep students and the presenters enthusiastic include:

- Energy conversion station development to demonstrate energy conversion
- Miniature plastic tokamak development with magnetic field to show magnetic confinement of a plasma
- Involvement of more staff member to present in the classroom in order to reach a larger number of students

Concluding Statement

The Scientist-In-The-Classroom program links the student with a scientist in an intimate way, bringing them together in the student's classroom. The student is asked to take an adventure in exploring scientific ideas and concepts with regards to plasma and fusion energy science research.

Students are enriched depending on their own curiosity. Plasma creation in the vacuum chamber, liquid nitrogen shrinking a balloon, seeing nature through the infrared spectrum via the infrared camera, and feeling the pull and vibration of magnets due to electrical currents leave a lasting impression that is remembered for years to come. Some students express interest in a science career and are visibly validated by meeting a scientist.

Everyone benefits from a program of this type. The student is excited about learning first hand, through hands-on equipment, the behaviors of matter's 4th state--plasma. They are challenged to understand the phenomenon presented and ask questions and offer explanations enthusiastically.   The presenter scientist helps to answer those questions, and is rewarded by seeing the student's interest. And lastly, teachers are rewarded through observing this transaction.

Everyone involved in the magical process of discovery grows.