Proceedings of the

Conference on K-12 Outreach from University Science Departments: 2008

NC STATE UNIVERSITY

BURROUGHS WELLCOME FUND

A Conference Hosted by
The Science House
North Carolina State University
Research Triangle Park, NC
April 8-10, 2008

Sponsored by the
Burroughs Wellcome Fund
Research Triangle Park, NC

David G. Haase and Sharon K. Schulze, Editors
Publication Date: December, 2008

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Forward

The 2008 Conference on K-12 Outreach from University Science Departments was held April 8-10, 2008, at the headquarters of the Burroughs Wellcome Fund in Research Triangle Park, NC. The Conference was organized by The Science House at North Carolina State University and supported through a grant from the Fund. Through invited and contributed talks and many individual and group discussions the Conference was concerned with the roles that scientists can take in improving and enhancing K-12 Science, Technology, Engineering and Mathematics (STEM) education. The invited speakers presented their roles in development of mathematics curricula, in the building of science outreach centers, in year-round support for teachers and in informal science education.

Over 50 participants from North Carolina, South Carolina, Alabama, Arizona, Nebraska, Tennessee, New York and Virginia represented university science and education departments, science research centers and museums, and K-12 schools and school systems.

The format of the 2008 Conference was similar to the 2005 Conference, whose Proceedings are found at www.science-house.org/conf. More time was spent in focused discussions about how to design and implement education projects. There were a reduced number of invited presentations, panel discussions, a poster session and discussions in small groups that worked together throughout the two-day program.

One objective of the 2008 Conference was to produce Proceedings that could be used as a guidebook for scientists new to STEM K-12. The invited speakers were recruited to deliver talks that provided illustrative "case-studies." These Proceedings include manuscripts prepared by four of the five invited speakers, a summary "primer" about scientists and K-12, and abstracts from the contributed posters.

About The Science House, North Carolina State University

The Science House is a learning outreach program of North Carolina State University whose mission is to partner with K-12 teachers to promote the use of hands-on learning in science and mathematics. The Science House operates teacher training, school support and student science programs that annually reach about 5,000 teachers and 20,000 students in over half of North Carolina's counties. Science House programs are guided by the best research and practices in science and mathematics education. The Science House enlists faculty and students at North Carolina's science, math, and technology university to train teachers and to help students visualize careers in these disciplines. In particular The Science House has led the K-12 outreach projects for multi-university science research centers that are at the cutting edge of their STEM disciplines.

The Science House website www.science-house.org distributes information on our programs as well as learning materials to support the NC science curriculum. The Science House site is a well-known resource in science education in NC, receiving over 50,000 visitors per month.

Located amid the high tech facilities of the NC State University Centennial Campus, The Science House includes 8,400 square feet of classrooms, offices, a teaching laboratory, and a computer-learning center. Regional offices in Asheville, Edenton, Jacksonville, Fayetteville, Lenoir, and Jacksonville, NC are hosted by school systems or education agencies and serve their surrounding communities and schools. Science House programs, services, and learning materials have also spread to Virginia, Georgia, Texas, South Carolina, Arizona and Kentucky.

About the Burroughs Wellcome Fund

The Burroughs Wellcome Fund is an independent private foundation dedicated to advancing the biomedical sciences by supporting research and other scientific and educational activities. Within this broad mission, BWF has two primary goals:

- To help scientists early in their careers develop as independent investigators
- To advance fields in the basic biomedical sciences that are undervalued or in need of particular encouragement

BWF's financial support is channeled primarily through six competitive peer-reviewed award programs—biomedical sciences, infectious diseases, interfaces in science, populations sciences, translational research, and science education.

- BWF's endowment: $791.2 million at the end of FY 2007
- BWF approved $54.4 million in grants during FY 2007

BWF makes grants primarily to degree-granting institutions on behalf of individual researchers, who must be nominated by their institutions. To complement these competitive award programs, BWF also makes grants to nonprofit organizations conducting activities intended to improve the general environment for science.

A Board of Directors comprising distinguished scientists and business leaders governs BWF. BWF was founded in 1955 as the corporate foundation of the pharmaceutical firm Burroughs Wellcome Co. In 1993, a generous gift from BWF's sister philanthropy in the United Kingdom, the Wellcome Trust, enabled BWF to become fully independent from the company, which was acquired by Glaxo in 1995. BWF has no affiliation with any corporation.

Dr. Enriqueta Bond, President of the Burroughs Wellcome Fund

Acknowledgements

We thank the Burroughs Wellcome Fund for its kind support and encouragement that made this Conference possible. Dr. Enriqueta Bond, Carr Thompson, Melanie Scott and Catherine Voron welcomed us to their Center and eased the process of arranging the Conference facilities.

Dr. Bond recently retired as the President of the Burroughs Wellcome Fund. On her watch the Fund began a substantial commitment to improving K-12 STEM education in North Carolina. This commitment has produced investments in student science enrichment programs, outreach programs from universities and the North Carolina Science, Mathematics and Technology Education Center. In its involvement in K-12 science and mathematics education in North Carolina, the Fund has set a standard to which the scientific community can aspire.

We also thank the several persons from other universities and research institutions who suggested speakers to invite. Becky Kirkland of NC State again produced photographs that display the energy and concentration of the Conference participants. Finally, we thank the members of the staff of The Science House who served as local hosts and saw to it that the program ran smoothly throughout.

Regina Barrier
Jason Painter
Colleen Karl
Shawn Reintjes
Janet Bailey
Mary Louise Bellamy
Joyce Hilliard-Clark
N. Scott Ragan
Pamela Gilchrist

Cherrie Tchir – Conference Secretary
David G. Haase – Conference Co-Chair
Sharon K. Schulze – Conference Co-Chair

CONFERENCE PROGRAM

Conference Schedule – 2008 Conference on K-12 Outreach from University Science Departments

Tuesday, April 8, 2008

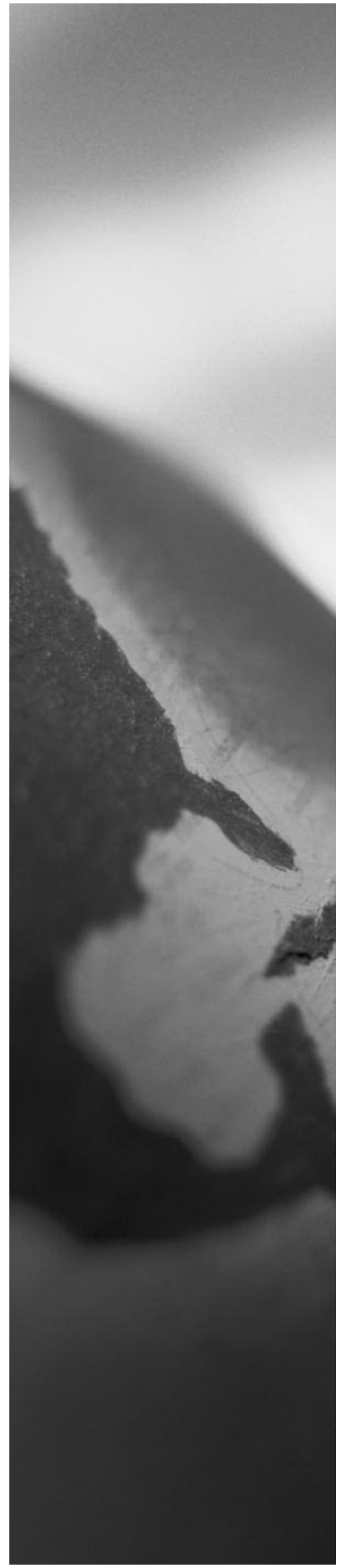
6:00 PM on	Arrival of out-of-town participants, Conference Hotel
6:30: 8:00 PM	Welcoming Reception, Conference Hotel

Wednesday, April 9, 2008

7:00 AM	Breakfast at hotel for out-town attendees, Conference Hotel
8:30 AM	Transportation to BWF Center, Conference Hotel
8:30 AM	Registration
9:00 AM	Opening Session: Welcoming and Introductions, Conference Co-Chairs and Carr Thompson
9:20 AM	Invited Talk 1: "How Can Mathematicians Help in K-12 Education? Experiences from the First Year of the Institute for Mathematics and Education" William McCallum, Department of Mathematics, University of Arizona
10:20 AM	Panel Discussion Respondent - Dorothy Sulock, UNC-A Respondent - Sarah Williams, UNC-CH
10:50 AM	Break
11:00 AM	Discussion Session 1: Discussion Outline
Noon	Box lunches and discussions

Carr Thompson of the Burroughs Wellcome Fund

1:00 PM	Invited Talk 2: "Breaking Down the Barriers: Creating Effective University-K-12 Partnerships" Virginia L. Shepherd, Vanderbilt University
2:00 PM	Panel Discussion
	Respondent - Jose D'Arruda, UNC-P
	Respondent - Kaye Storm, Stanford
2:40 PM	Break
3:00 PM	Discussion Session 2: Discussion Outline
4:15 PM	Conclusion of the Day
6:00 PM	Reception and Poster Session at Hotel/Cash Bar, Conference Hotel
7:00 PM	Dinner at hotel/No program, Conference Hotel



Thursday, April 10, 2008

7:00 AM	Breakfast at hotel for out-town attendees, Conference Hotel
8:30 AM	Transportation to BWF Center, Conference Hotel
9:00 AM	Invited Talk 3: "The Education/Outreach Figure of Merit: Making a Difference without Making Yourself Crazy." Diandra L. Leslie-Pelecky, University of Texas at Dallas
10:00 AM	Panel Discussion
	Respondent - Sandra White, NCCU
	Respondent - Kristin Walker, UNC-C
10:30 AM	Break
10:45 AM	Invited Talk 4: "It Only Takes One" Marllin Simon, Auburn University
11:45 AM	Box lunches Discussion session 3: Discussion Outline
1:00 PM	Invited Talk 5: "Telling a Story about the World that is Too Small to See" Carl Batt, Cornell University
2:00 PM	Discussion Session 4: Discussion Outline
2:45 PM	Concluding Statements/ summary and farewell Conference Co-Chairs
3:00 PM	Conclusion of the Conference
	Depart to hotel, airport, home

The Conference Discussions followed the format described in the 2005 Conference on K-12 Outreach from University Science Departments, available at www.science-house.org/conf

Introduction - Scientists and K-12 STEM Education

Dear Science, Technology, Engineering or Mathematics (STEM) Professional,

The co-editors of these Proceedings have spent much of their careers helping scientists and engineers to work productively in K-12 STEM education. In this short "primer" we will describe the ways STEM professionals can work with K-12, provide some references to start you off, describe the K-12 education environment and finally give you a glossary to help you understand education conversations.

In the first Proceedings Ramon Lopez outlined three levels of engagement of scientists in K-12 - Outreach, Education and Reform. (Proceedings 2000, p. 99, found at www.science-house.org/conf/) A scientist presenting a physics demonstration at her child's classroom is doing Outreach. A scientist partnering with others to develop math curriculum materials is participating in Education. A scientist who collaborates in improving the state science curriculum, is engaged in Reform. Roger Bybee and Cheri Morrow (Newsletter, APS Forum on Education, Fall, 1998, http://www.aps.org/units/fed/newsletters/upload/fall98.pdf) proposed a similar description of levels; the scientist as Resource, Partner and Advocate.

Many STEM professionals become involved with K-12 when their children reach middle school, and the STEM parent has to consult on science projects, or talk about science to the child's class. Some STEM's look to K-12 education when they are planning their first Broader Impacts statement for an NSF research proposal. These are the initial steps down the path of Outreach, Education and Reform. In Outreach the STEM retains the position as a science expert and is truly a visitor into the classroom. A STEM involved in Education is partnering with other K-12 stakeholders and learns about K-12 issues such as curriculum or teacher certification. In Reform the STEM works to improve the entire system for the better. A fascinating result for the STEM is that K-12 engagement develops partnership and leadership skills a STEM needs for success in research and university education.

It is important that STEM professionals understand that K-12 education is quite different and much more complicated than science. There are, however, many good resources help the STEM make the first steps, including these Conference Proceedings.

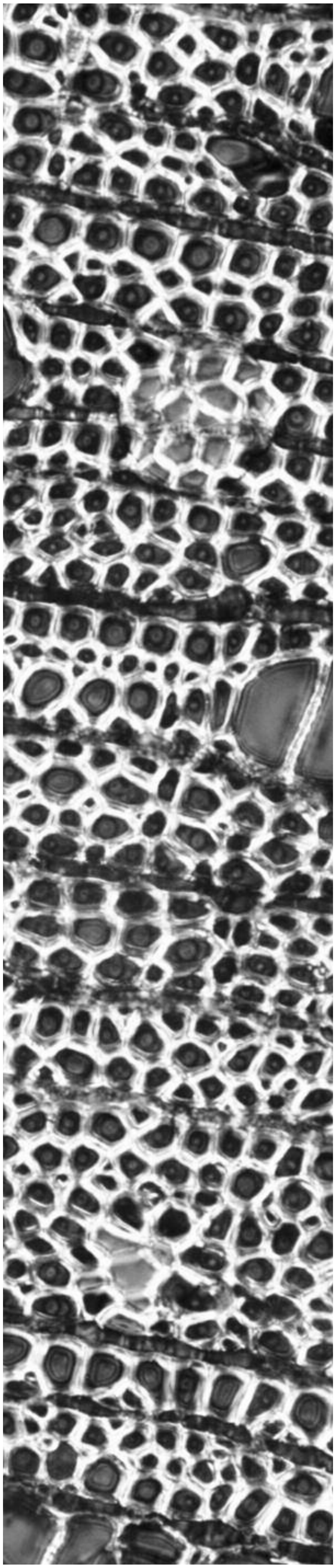
What information do you need begin the journey, to do good for K-12 education, and to be successful enough to encourage you to do more?

First Steps – Outreach

Outreach begins with listening and learning. In the beginning you should realize that as a STEM you know very much about your field of science and probably very little about how K-12 education works. You may not have entered a K-12 school since you were a K-12 student. Your value to K-12 is that you know your field, you use the scientific process, and you are very enthusiastic about what you do. You can be a great resource to the classroom and the teacher and a role model for the K-12 students.

But you have much to learn about how K-12 education works. You will find K-12 students with diverse backgrounds, interests and levels of attainment. You will find many dedicated teachers who may not know as much science as you do, but everything about educating their K-12 students. Your visit to a classroom is an opportunity for you to listen and to learn from those teachers.

Outreach can include visiting a school, helping with a science fair, assisting in a program at a science museum or a summer camp, leading a science-related merit badge program for scouts, or being a guest



speaker for a teacher-training workshop. In each of these cases there is an audience of students or teachers, the STEM, and someone such as the K-12 teacher or museum educator or camp counselor, who brings it all together. At the Outreach stage you should look for opportunities to connect to such education professionals. They can teach you much about K-12 students and teachers and provide you with Outreach opportunities where you can succeed.

The first resource that every STEM should access before working with K-12 is *Resources for Involving Scientists in Education* (RISE), a website maintained by the National Academy of Sciences (http://www.nas.edu/rise/). This contains information about all the K-12 issues that a STEM needs to know.

Before entering any classroom you should read *Sharing Science With Children: A Survival Guide for Scientists and Engineers* (http://www.nas.edu/rise/roles1a.htm). This short pamphlet outlines the basics you need about bringing your science to the classroom. Every STEM mom or dad should read this before visiting their child's fifth grade classroom.

The 2000 - 2008 Conference Proceedings contain many articles useful to the new STEM Outreacher. They describe different types of programs for scientists as Outreachers, Educators, and Reformers. There are also references on issues in K-12 STEM education for students from under-represented groups and outreach from Science Research Centers. Because the NSF Broader Impacts are a motivator for STEM's to work with K-12, we have added a list of favorite Broader Impacts resources.

Examples of Outreach Activities from Previous Conference Proceedings
All are archived at www.science-house.org/conf/

Effective Strategies for Linking Scientists with K-12 Teachers and Students: Lessons We Have Learned Over Five Years, Mary Louise Bellamy (Proceedings 2005, p. 42).

Finding the Circumference of the Earth: A Collaborative Outreach Project at a Local Middle School, Judy Beck and Nancy Ruppert (Proceedings 2005, p. 31)

Retired Scientists and Engineers: Providing In-Classroom Support to K-12 Science Teachers, Christos Zahopoulos, (Proceedings 2003, p. 42)

Developing UNCW Science Graduate Students as Middle School Resources, Sue M. Kezios, William B. Harris and Karen Shafer (Proceedings 2003, p.82).

Making the Connection to the Real World: Industry and Research Experiences for Teachers and Students, Sandra Harpole (Proceedings 2001, p. 51)

Examples of Education Activities from Previous Conference Proceedings

Long Term Support for Science Partnerships, Donald Mitchell (Proceedings 2000, p. 35)

Alabama Science in Motion: A Decade of Secondary Science Outreach, John Halbrooks (Proceedings 2004, p. 56)

Examples of Reform Activities from Previous Conference Proceedings

Increasing Student Achievement: The Goal for University Outreach to the Public Schools, Charles Coble (Proceedings 2000, p. 91)

Science Education Reform and Roles for Scientists, Engineers and Their Organizations, Ramon Lopez (Proceedings 2000, p. 99)

STEM Education for Students from Under-represented Groups

Startling Statements, Jose Franco (Proceedings 2000, p. 81)

Equity in Outreach: Measuring the Difference, Jane Butler Kahle (Proceedings 2001, p. 21)

Equity: What, Why and How, Karen Charles (Proceeding 2001, p. 21)

Partnering Across Cultures: Bridging the Divide Between Universities and Minority High Schools, Marion Usselman and Gordon Kingsley (Proceedings 2004, p. 63)

Outreach from Science Research Centers

Utilizing Technology to Integrate Research and Learning at the National High Magnetic Field Laboratory, Karl Hook (Proceedings 2002, p. 43)

Research Experiences for Teachers: The Impact on Teachers and Students, Jay Dubner (Proceedings 2003, p. 21)

Expanding the Role of Universities in K-12 Science Education, Stephen L. Hajduk ((Proceedings 2003, p. 64)

SDSC Science Enrichment Program: A University and Community Partnership to Enhance K-12 Science Education, Rozeanne Steckler (Proceedings 2003, p. 36)

Creating an Effective Interface Between the Ocean Sciences and Education, Lundie Spence and Carrie Thomas (Proceedings 2004, p. 24)

References about Broader Impacts from the NSF and elsewhere

The National Science Foundation's inclusion of the "Broader Impacts" Criteria 2 in the proposal review process has motivated many STEMS to contribute in some way to K-12. This is described in Dr. Leslie-Pelecky's article in these Proceedings. Because Broader Impacts have become so important for individual scientists and research collaborations, we provide the following references.

NSF issued Important Notice 127 entitled "Implementation of new Grant Proposal Guide Requirements Related to the Broader Impacts Criterion" http://www.nsf.gov/pubs/2002/iin127/

An NSF document defining Broader Impacts titled "Merit Review Broader Impacts Criterion: Representative Activities" www.nsf.gov/pubs/2003/nsf032/bicexamples.pdf

The NSF Office of Polar Programs has a similar overview of representative examples http://www.nsf.gov/od/opp/opp_advisory/oaccrit2.jsp

The CIRES website has references to other NSF documents about Broader Impacts cires.colorado.edu/education/k12/rescipe/collection/impacts/

American Chemical Society Fall, 2005 Broader Impact Showcase http://chemistry.clemson.edu/NSF-broaderimpactsposters

The Integrating Research and Education site at Carleton College has references for Broader Impacts information in the Earth Sciences http://serc.carleton.edu/research_education/linkage.html

The slides from a presentation at an FIE conference titled "Interactive Session - The NSF Broader Impacts Criterion-Why And How," Sue C Kemnitzer, Roger K. Seals and Krishna Vedula http://fie.engrng.pitt.edu/fie2004/papers/

“Professional Development Needs and Outcomes for Education-Engaged Scientists: A Research-Based Framework,” H. Thiry, S. L. Laursen, and A. Hunter, Journal of Geoscience Education, v. 56, n. 2, May, 2008, p. 235.

Some Background About K-12 Science Education

Public K-12 education in the US is an intensely local and political enterprise. Most young people seem to assume that there were always high schools, that students always were expected to complete twelve grades and that the curriculum has not changed since great-grandma was a teenager. They also may assume that every school is the same.

The notion that all American students should attend high school was unknown in the 1800’s. Although the federal government has become more and more involved in education since the civil rights developments of the 1960's and the establishment of the Department of Health, Education and Welfare in 1953, public education remains a local and state function.

In many states the schools are operated by local school districts, governed by local school boards. The funds for operation of the schools come from a combination of local and state funds. The state in some way sets requirements on the curricula and graduation requirements. Within these bounds there is significant variations among the states. For instance, in some northern states there are many school districts, each may include only one town and one high school. In North Carolina, most of the small local school districts have been consolidated into county districts. In North Carolina the teachers are paid from state funds, which the local districts are responsible for buildings and operations costs. The state sets the curriculum through a Standard Course of Study. The federal government provides funds for a variety of education programs. Some of these funds are distributed on a pass-through basis to the state school system and to the local school districts. The state and the federal government maintain curriculum oversight through the student testing programs, some of which were mandated by the federal No Child Left Behind Act (2001).

Teachers are not the same in each state, either. In some states teachers belong to a union; in others not. The certification requirements (the rules that allow a teacher to work at a school) are set by a state agency and vary from state to state. Although the federal government sets guidelines for "highly qualified" status, this can vary from state to state. Some states have crying needs for qualified teachers, other states export their newly graduated teachers.

A Glossary of K-12 STEM Education Terms

K-12 education, like any other community, has its own meanings for certain words. The following are informal definitions to help the scientist navigate communication with K-12 educators, administrators and policy makers. We have heard these words very often misheard, misused and misunderstood in meetings of STEM's and educators.

Alternative Licensure – Not all teachers went through the College of Education for a four-year degree. Many teachers come into the classroom from another profession and received certification through an alternative program of courses. For instance, a retired Navy officer might end up teaching middle school math by taking a set of prescribed education courses and completing a set of examinations.

Board Certification – Teachers may apply for National Board Certification from the National Board for Professional Teaching Standards. In this process the teacher must complete requirements such as preparing a teaching portfolio and completing an exam. The certification is in a particular area of education. Evaluations have shown that NTBC certified teachers are more effective in the classroom than their colleagues who did not become certified. In some states teachers received substantial pay increases for achieving Board Certification.

Educator – Sometimes an educator is simply a teacher or education administrator. Science museums employ educators who work on the museum floor or lead education programs. Sometimes an Educator is someone who is a faculty member in the College of Education. A scientist is not an Educator.

Evaluation – In experimental science, the scientist does the experiment and analyzes and reports the results. In education the project does the work and an external evaluator is often hired to observe the project, collect data and report the results to the funding agency.

Hands-on Learning – A way of teaching in which the students do experiments, brief or extended. Not to be confused with Inquiry-Based Learning.

Highly Qualified Teacher – This term comes from the No Child Left Behind legislation, but is interpreted on the state level. One might expect that a Highly Qualified high school science teacher would have substantial expertise in their science area, normally from completing college-level courses. Maybe the person would have had a science major. However, Highly Qualified may only mean that the person has a general science teaching license.

High Stakes Testing – Even before No Child Left Behind some states had statewide student end-of-year or end-of-course examinations. Sometimes these exams, such as the Regents Exams in New York are used to determine students' grades or the status of their diplomas. These exams became High Stakes when the exam outcomes were used to evaluate the effectiveness of teachers and schools. For instance, in North Carolina schools that perform well on the end-of-grade exams the teachers received pay bonuses. Teachers and principals at low performing schools may be removed. No Child Left Behind includes several levels of penalties for low-performing schools and allows parents the right to move students to other schools in a district.

Informal Science Education – A process that informs the public about science, for instance, museums and their many education lectures, exhibits, camps, and short courses. Informal science educators may have formal K-12 teaching experience or certification. Informal Science Education programs are important resources to STEM's because they are able to address current science topics unfettered by the Standard Course of Study.

Inquiry-Based Learning – A way of teaching in which the students are led to their understanding of the topic through a set of inquiries. There are several "flavors" of inquiry-based learning. Although the concept is widely espoused by educators, "inquiry-based" teaching can vary drastically from one classroom to another.

Lateral Entry Teacher – A person who entered teaching without going through a standard four-year undergraduate teacher preparation program.

Partnership – A collaboration of persons and groups gathered to address a common goal. Examples are public-private partnerships, school-university partnerships, corporate-school partnerships. To be successful a partnership should include enough partners to successfully achieve its goal and to sustain the results. In a good partnership each partner will share in the responsibilities, expertise and the benefits of the activity. No partner holds all the answers nor controls the outcomes. Decisions are reached through consensus. The calls for proposals from some foundations are quite prescriptive about the composition and activity of the partnerships for K-12 education projects.

Professional Development – This was called Teacher Training in the days when teachers attended one-day seminars to learn about a new teaching technique or content topic. No longer. The seminars still exist but there are many other strategies for improving teaching, such as a year-round study group of teachers in a school. The basic reference on types of teacher professional development is Loucks-Horsley, et al., *Designing Professional Development for Teachers of Science and Mathematics*.

Research-Based Instruction – This is an instructional model that adheres in some way to an instructional strategy that has been demonstrated to be effective in a published research report. This is an exceptionally loosely construed term. For instance, the term could mean that the instruction slavishly conforms to every detail of an instructional strategy reported in the literature. It could also mean that the instruction uses some of the components of the strategy reported in the literature.

School District – The basis of American public education is the local school district, overseen by a local school board and a school superintendent. Although the state may dictate the curriculum and may provide a large part of the funding for the schools, the day-to-day management is the purview of the school board, whose members are elected from the community. Much of the variability of the quality and effectiveness of the schools are dependent on the quality of the board and the politics and resources of the local community. If all politics is local, then certainly all education is local.

Stakeholder –A person, group or organization that will be affected by the operation and outcomes of a project. For instance, in a high school, the stakeholders are the teachers, administration, students, parents and the community. Partnerships should seek to involve enough stakeholders to assure the project has enough input and participation to succeed.

Standard Course of Study – a document issued by the state education agency which outlines what topics will be taught, in which grades. The Standard Courses of Study has slightly different names in different states and the detail of the SCOS varies greatly among the states. States may use their own judgments in constructing the SCOS but often refer to the National Science Education Standards or Project 2061 in doing so. Because the SCOS dictates what will be taught, and presumably what will be tested, it is developed through iteration with schools, teachers and other stakeholders. During each revision there are often controversies about the inclusion of global warming, human sexuality, evolution and the origin of the universe.

Standards-Based Instruction – This is an instructional model that adheres in some way to an instructional strategy described, for instance, in the National Science Education Standards.

STEM Professional – Someone who works in the areas of Science, Technology, Engineering or Mathematics. Examples are university faculty, medical professionals, workers in corporations or government offices who use STEM disciplines in their activities. Some construe STEM's to include people who may have 2-year degrees or high school diplomas yet work in technical areas.

Teacher Licensure or Certification – In order to teach in a public K-12 school a teacher must be licensed in some way. This may not be needed for teaching in a private school. Licenses are issued by the state education agency and each state has its own requirements for licensure, the types of licenses. For instance, in North Carolina, a high school general science license, permits a teacher to teach any high school science topic, whether or not the teacher took the topic in college.

Teaching With Technology – To a scientist this usually means doing experiments using up-to-date laboratory equipment, often computer-interfaced, that provide substantive measurements. This is sometimes found in high schools. In K-12 teaching with technology means using computers, powerpoint presentations, email and the internet. Technology teachers in high schools often teach how to use the internet and word processing and spreadsheet programs.

Breaking Down the Barriers: Creating Effective University-K-12 Partnerships

Virginia L. Shepherd, Ph.D.
Professor of Pathology
Director, Center for Science Outreach
Vanderbilt University
Senior Career Scientist, Department of Veterans' Affairs

Introduction

At a time when national priorities are calling for top performance and achievement in science, math, and technology, many of our students in the U.S. are falling behind other countries [1,2]. At the local level, school districts are attempting to stem declining scores by forming partnerships with outside entities, in particular local universities that offer expertise in content areas. In response to this challenge, Vanderbilt University has made a commitment to partnering with K-12 classrooms through the creation of the Center for Science Outreach (CSO) whose mission is to connect scientists to K-12 teachers and students to enhance science literacy and to increase the number and diversity of students entering the science career pipeline [3].

Numerous outreach programs linking university scientists and K-12 classrooms have been developed throughout the U.S. Although the emphasis in these programs has moved from traditional course offerings and degree programs for teachers to university-K-12 partnership models [4], many are not coordinated across the university and remain as separate projects developed within individual science departments. Several key features of the Vanderbilt CSO highlight the importance of coordinating outreach efforts to promote effective university-K-12 connections. First, the CSO was established by Vanderbilt University as a trans-institutional center to centralize outreach efforts across the schools of Medicine, Arts and Science, and Engineering. This has allowed the CSO to reach faculty and students in all STEM departments and has coordinated partnership activities. Second, the university has committed financial resources for the development of programs that are not reliant upon grant monies, thus sustaining programs that might not be possible in other university settings. Third, many university outreach programs are scientist-driven, with little input from teachers and students. The CSO has made a commitment to understanding the needs of teachers and students in the K-12 community and is staffed accordingly with Ph.D. scientists, K-12 teachers, and scientist-educators. These unique characteristics have allowed the CSO to expand and sustain outreach efforts in partnership with the K-12 community to enhance science achievement.

The evolution of the CSO has spanned a ten year period of creating partnerships with both the university and the K-12 community at a time when neither understood the value of such partnerships. Much of the groundwork laid involved changing attitudes and fighting against an establishment not quite ready to accept the challenges. However, many changes over the past several years, including the continued decline of science achievement by U.S. students and failing school systems, have contributed to an understanding by universities of their responsibility to help reduce the achievement gap in the sciences. Through the establishment of the CSO, Vanderbilt University has been a leader in creating effective and sustained partnerships between university scientists and K-12 districts to further the goal of increasing science achievement and strengthening the diversity of students entering the scientific pipeline. The goal of this article is to highlight three specific Vanderbilt CSO programs, and to present a description of each program, impact on the target audiences, and the development of the key partnerships involved.

Major Programmatic Areas

Three principal areas have been the focus of program development and implementation in the CSO over the past decade (Table 1). CSO *in-classroom programs* have placed scientists directly into local and national classrooms in person or virtually. For example, the Scientist in the Classroom Partnership (SCP) program teams graduate students and postdoctoral fellows in the STEM disciplines with middle school teachers to present hands-on science activities one day per week. The CSO Virtual Scientist program connects university researchers with classrooms throughout the world using live interactive videoconferencing [5]. Our *student-centered programs* have included such on-campus programs as summer camps for middle school students, a research internship program for high school students, and our unique one-day School for Science and Math at Vanderbilt (SSMV) in partnership with the local school system (Metropolitan Nashville Public Schools – MNPS). The *teacher-centered programs* have brought teachers to campus for intensive research experiences, provided short- and long-term workshops focusing on science content, developed a master's degree in science for teachers, and developed a new program to prepare Ph.D. scientists for secondary teaching careers. Overall, hundreds of teachers and thousands of students have been impacted by these programs. Equally important in the development of these programs is the change in commitment at the university level. Faculty and graduate student participation has increased dramatically during this time, presentations by CSO staff to individual departments are regular features of CSO functions, the CSO routinely works with university researchers to write effective broader impact statements for grant applications, and the CSO is considered by the general faculty to be a central point for coordination of science educational outreach activities for the Schools of Medicine, Arts and Science, and Engineering. One program from each of the three programmatic areas is discussed in detail below, highlighting results and impacts to date as well as the development of the primary partnerships involved in each program.

Program: Scientist in the Classroom Partnership (SCP) Program

Partners: MNPS, Vanderbilt University, Meharry Medical College, Tennessee State University, Fisk University

The National Research Council has stated that rapid and extensive improvement of science education is unlikely to occur until it becomes clear to scientists that they have an obligation to become involved in elementary- and secondary-level science [6]. It has been proposed that scientist-teacher collaborations may be an effective way to facilitate an understanding of scientific inquiry and to increase the content knowledge of science teachers [7,8]. The current GK12 program through the National Science Foundation recognizes that teaching of STEM disciplines at the K-12 level can be enhanced through partnering STEM graduate students at institutions of higher learning with K-12 teachers to improve the STEM content taught in their classes [9]. Vanderbilt was the lead institution on one of the original GK12 grants (2000-2007), in partnership with Meharry, TSU, and MNPS. During the course of this program, over 100 graduate and undergraduate students from the participating universities have partnered with more than 80 teachers in 15 MNPS middle school science classrooms. Graduate teaching fellows (Fellows) taught with their partner teachers in the middle school classroom for two days per week, and participated in support activities and programs including education courses and workshops. The impacts of the program included enhanced teaching and communication skills on the part of the Fellows, increased understanding of and knowledge about science by the teachers, and enhanced science learning by the middle school students [10-12].

The current Scientist in the Classroom Partnership (SCP) program is the sustained initiative stemming from this highly successful GK12 program. The current SCP program follows the model developed in the GK12 program, and recruits ten Fellows (undergraduate and graduate students and postdoctoral fellows) per year from each of the four universities, and ten teachers in 8-10 middle schools in MNPS. Fellows spend one day per week in the classroom, and attend a monthly seminar and summer team-building workshop. The program has been institutionalized within the universities as well as the school system, and is now funded through a combination of university and MNPS funds. An additional volunteer component to the overall program was added this past year, with graduate students partnering with specific schools and teachers. Volunteer Fellows enter classrooms and schools a minimum of one hour per month, and participate in a half-day orientation at the beginning of each semester. Overall, the program has not only strengthened inter-university ties as well as university-K12 connections, but has enhanced the overall outreach commitment by university Fellows and faculty.

Program: The School for Science and Math at Vanderbilt (SSMV)

Partners: Metropolitan Nashville Public Schools, Nashville Alliance for Public Education (NAPE), State of Tennessee Department of Education, Vanderbilt University

The SSMV is a unique one-day school for highly motivated and talented students from MNPS. The program is supported through funding from the National Institutes of Health, Vanderbilt University, NAPE, and MNPS. Twenty-five students from each of the high school grades are selected to attend based on their grades and test scores, personal essays, teacher recommendations, and interviews. Approximately 130 students applied in each of the first two years of the program, and represented over half of the MNPS middle schools. To establish the model, negotiations between the CSO, MNPS and the Tennessee State Department of Education agreed on the following commitments:

- Vanderbilt would provide space and partial funding;
- The State would designate the academic year and summer courses as one honors credit each;
- MNPS teachers would provide missed day homework assignments in advance for the students;
- MNPS would provide a liaison to work with the SSMV Director to ensure that students' schedules would accommodate the missed day of school;
- The CSO would provide a Vanderbilt liaison to work with teachers and counselors to ensure the success of the students;
- SSMV would provide a mentored two-hour study tutoring session immediately following class time to assist students with MNSP zoned school assignments.

In the SSMV program, students commit to participation in the academic year and summer program for all four years of their high school student. In the academic year, students attend class on the Vanderbilt campus for one full day per week, and participate in a three week research course in their post-9th and -10th grade year. Following their 11th grade year students enter a research laboratory at Vanderbilt and conduct an independent project under the mentorship of a faculty member and his/her research group. In the 2008-2009 academic year, 26 freshman, 24 sophomores and 10 seniors will

attend the SSMV, representing 12 of the 16 MNPS high schools.

The central theme of the SSMV curriculum is a research-centered approach, with students learning science through an understanding of how to ask a good question and how to formulate hypotheses. In the 9th grade, each day centers on a specific interdisciplinary science question, with a format combining discussion and laboratory activities led by the SSMV faculty interwoven with university faculty or student guest lecturers, demonstrations, and visits to science laboratories. The 10th grade curriculum delves deeper into specific science topics through a curriculum designed around the AAAS "Top 125 Science Questions"[13]. An open source program (Moodle) is used to extend the SSMV learning community virtually beyond the one day model, using the Internet for submission of weekly challenge homework assignments, online office hours, real time instructor-student discussions, student- and faculty-led discussion boards, and program evaluation. Assessment of student work is a combination of class participation, submitted work, and laboratory notebooks and reports.

Evaluation of the program is being conducted by an external evaluation team, using a quasi-experimental research study that will compare students in the SSMV to a matched control group to determine the impact on student achievement and preparation for STEM careers. The evaluators are working closely with the MNPS Office of Assessment to determine control group criteria and to develop data transfer protocols. Evaluation results from the first year indicate that students have a high degree of satisfaction with the program, are able to keep up with their regular high school assignments, enjoy learning science from real scientists, and are part of a unique learning community. Initial findings also suggest that a strong partnership has developed with the public school system that gives students honors credit for courses, and that the program is impacting the culture of the university with over 100 faculty members, staff, and students involved during the first school year.

Program: Secondary Certification for Ph.D. Scientists

Partners: Vanderbilt University Schools of Medicine, Education, Arts and Science, Engineering

It has been estimated that the U.S. will need as many as 240,000 new science and math teachers over the next decade [14]. Finding and retaining high quality teachers will present huge challenges for local school districts. At the same time, many of our current science postdoctoral fellows are spending more time in training and are finding fewer available faculty positions [15]. With the right programs and incentives in place, both of these problems could hold the solution for the other [16]. The National Science Board recently issued a statement – America's Pressing Challenge – emphasizing that a quality workforce is essential providing a "world-class education in the STEM disciplines for all Americans" [17]. The question then becomes, are Ph.D. scientists interested in teaching at the secondary level? The National Research Council published a two-part report stating that there is a much higher level of interest in secondary teaching among Ph.D.s than the approximately 1% currently in K-12 science and math classrooms [18]. The report goes on to state that as many as 36% of Ph.D.s have considered teaching at the secondary level. These professionals bring with them not only a passion for science, but a depth of knowledge and a deep understanding of the true process of science. Further, a recent study has shown that those professionals who choose teaching as a second career have a strong desire to teach and are more likely to teach in urban settings [19]. To determine the level of interest in K-12 teaching within the biomedical science departments at Vanderbilt, a survey was sent to all graduate students and postdoctoral fellows (Table 2). Of approximately 800 possible respondents, 135 replied, with 55% stating an interest in K-12 teaching as a career, and 72% indicating that they would be interested in a teaching certification program designed specifically for Ph.D. scientists.

With their depth of knowledge, Ph.D. scientists could provide an important source to fill the demand for secondary science teachers. According to a recent study, student achievement increases by almost 40% of a grade level in science and math when teachers have a major or minor in the subject matter [20]. However, research suggests that the pedagogical preparation and quality of classroom teaching practices makes an even greater difference [21]. In addition, well-prepared teachers are more likely to remain in the profession, suggesting that the initial preparation program as well as the support of the teachers as they enter the profession is critical for these new teachers to survive their beginning years and remain in the profession [22,23]. Research also indicates that well-prepared teachers have the largest impact on high student achievement [22,24,25]. However, many of our graduate and postdoctoral programs do not provide teaching experience or any pedagogical coursework. Therefore, what is critical for attracting and retaining Ph.D.s to secondary teaching is a program that focuses on combining in-classroom experience and mentoring with formal instruction in pedagogy, combining effective but practical education courses building on the scientific content and research knowledge these teachers would take into the classroom.

In response to this, the CSO has worked closely with the Department of Teaching and Learning at Vanderbilt's Peabody College of Education to design a certification program for Ph.D. scientists as summarized in Table 3. First, we are proposing to link two highly ranked schools at Vanderbilt, one focusing on training of scientists and the other on teacher preparation, to offer a program of study that will allow senior graduate students and postdoctoral fellows in the STEM disciplines to prepare for a career in secondary science teaching while completing their scientific research training. Second, we are building on our SCP program which will provide the in-classroom internship piece, with essential coursework provided by the School of Education's Department of Teaching and Learning and the Center for Science Outreach (CSO) at the Medical Center. Third, our program places an emphasis not only on scientific expertise, but also on a commitment to teaching and demonstration of exceptional teaching skills. The length of the program and the integration into the Peabody College teacher preparation program at Vanderbilt will ensure that these scientists are exceptionally well-prepared and have a better outcome potential than many of the shorter duration programs.

Conclusion: Lessons Learned and Challenges Remaining

The Vanderbilt CSO has overcome numerous challenges and barriers during the past decade. Some of these challenges remain, and each university will need to assess their response to these challenges as they move toward coordinating campus-K-12 partnerships. First, where state universities may have a mandate to reach out to the community at large, this is not always a part of a private university's mission. Private and public universities must make this a priority in their institutions, and dedicate funds as well as faculty and student time to commit to service activities. Second, leadership is constantly changing in both the higher education and K-12 arenas. For example, Vanderbilt has a new Chancellor, Provost, and two open dean positions; the Mayor of Nashville took office this past year; and MNPS is currently searching for a new Director of Schools. How can one sustain partnerships in this ever-changing administrative world? Will the ties that are created be strong enough to survive new leadership directions? Finally, national leaders, funding agencies and advocacy groups have been consistently calling for increased funding for our public schools, to introduce new programs that will challenge our students to achieve at higher levels. We all realize that we have reached a critical point in determining the survival of our public educational system; the funding must not only be sustained, but continue to grow to ensure that we provide the best educational opportunities to prepare our children for the questions they will face in their future.

Creating effective partnership that will contribute to enhanced science literacy will require the involvement of a core of passionate people in all of the partner institutions: from universities and local school systems to local and state governments. In addition, each partner must be willing to commit financial resources to integrating programs with demonstrated impact into the fabric of each institution. All partners must be involved in substantive ways in the design, implementation and evaluation of programs. And, finally, all partners must work toward developing a level of trust and respect that will be essential to successful outcomes.

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Table 1. Major CSO Programmatic Areas

Programmatic Area	Inclusive Years	Target Audience	Principal Partners	Funding Sources
In-Classroom Programs				
Interactive videoconferencing (Virtual Scientist)	2000-pres	Middle and high school classrooms	VU; independent and public schools (local and international)	NIH, VU
Scientist in the Classroom Partnership (SCP)	2000-pres	Middle school classrooms	VU, MMC, TSU, Fisk, MNPS	NSF, MNPS, VU, MNPS, TSU, NSF
Student-Centered Programs				
Summer camps	1998-pres	Middle school students	VU, independent and public schools (local and national), Discovery Health Channel	VU
Summer research internship program (RIP)	2006-pres	High school juniors	VU, independent and public schools (local and international)	VU
School for Science and Math at Vanderbilt (SSMV)	2007-pres	9-12th students	VU, MNPS	NIH, VU, MNPS, NAPE
Teacher-Centered Programs				
Summer content workshops	1992-pres	Middle and high school teachers	VU, independent and public schools (local and international)	NIH, State of TN, VU
Masters in Lab Investigation (MLI)	2008-pres	Middle TN teachers	VU, State of TN, MNPS	VU, State of TN
Secondary certification for Ph.D. scientists	2008-pres	VU graduate students/postdocs	VU (Med, Arts and Science, Engineering and Educ Schools)	VU, State of TN

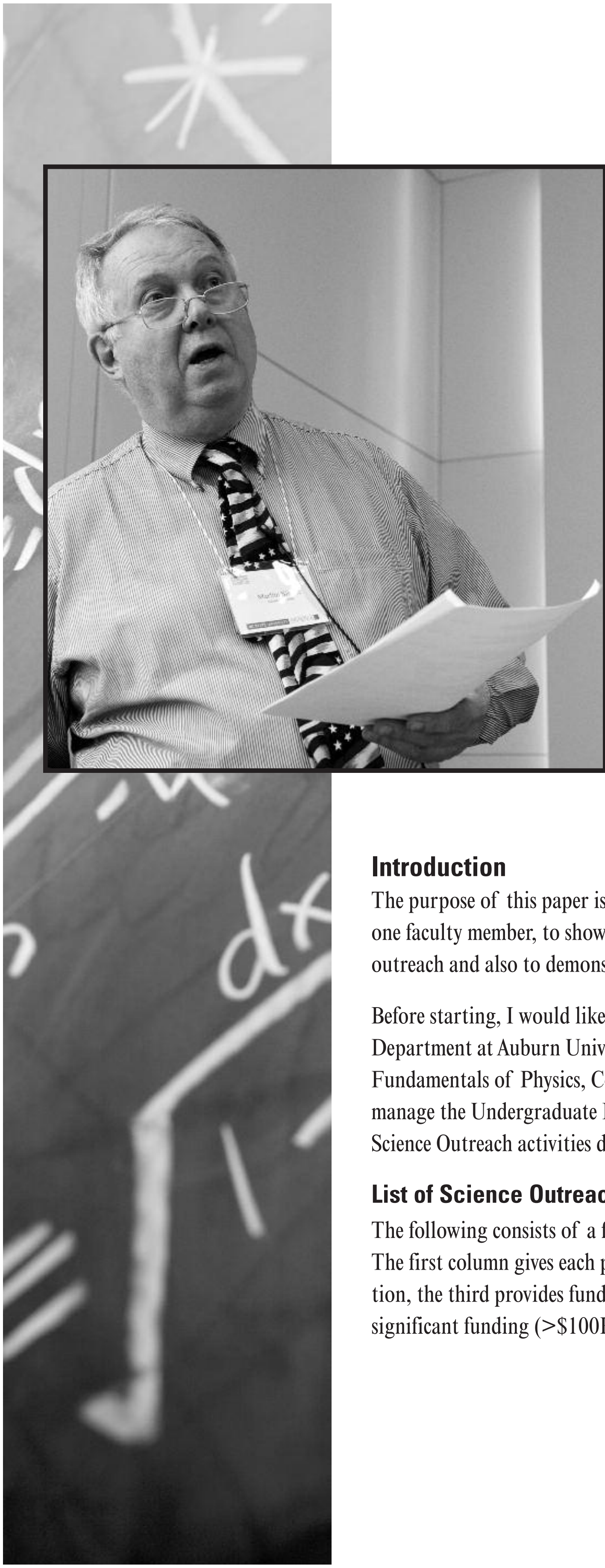
Abbreviations: VU=Vanderbilt University; MMC=Meharry Medical College; TSU=Tennessee State University; Fisk=Fisk University; MNPS=Metropolitan Nashville Public Schools; NAPE=Nashville Alliance for Public Education; NIH=National Institutes of Health; NSF=National Science Foundation

Table 2. Results of a Survey of School of Medicine Graduate Students and Postdoctoral Fellows to Determine Interest in a Secondary Teaching Career

Question	# of Respondents	# Yes	# No
Would you be interested in a career teaching at the high school level?	135	73	62
Would you be interested in a teaching certification program designed for PhD scientists by PhD scientists?	135	97	38
Would you be interested in a certification program that is lost cost but requires a commitment of 2 yrs in the public school system?	135	49	86
Would you be interested in secondary teaching if:			
It included a mentoring component by master teachers and scientists?	135	75	60
You were guaranteed a research position during the summer months?	135	68	67
You were guaranteed specific benefits provided by Vanderbilt?	135	85	50
Science graduate students from Vanderbilt were assigned to help in your classroom 1 day/week?	135	73	62
Are the following reasons important in choosing teaching as an alternative career:			
Summers off	135	84	51
Salary (MNPS salary for PhD with no experience is $44,718)	135	76	59
Choice of high schools	135	76	59
Choice of courses to teach	135	101	34
Are you interested in receiving further information?	53	53	--

Table 3. Proposed Ph.D. Certification Program

	Course	Credit Hours	Description
SUMMER I	Science Methods	3	Survey of trends in science teaching at the middle and high school levels. Emphasis on philosophies, teaching strategies, materials, and research associated with current curriculum practices
	Seminar	0	Three-week workshop in preparation for entering middle school classrooms: classroom management, curriculum planning
ACADEMIC YEAR I	Scientific Literacies	3	Study of literacy assessment research and practices, opportunities for collecting and analyzing data using multiple assessment tools, and methods for implementing diagnostic findings (fall semester)
	In-Classroom Internship	0	Team teaching with partner teacher in 7,8 science classroom (academic year)
	Analysis of Teaching Seminar	1	Weekly seminar to discuss challenges and issues confronting secondary science teachers (academic year)
	Student Teaching	2	Student teaching in 7,8 classroom (spring semester - 3 weeks)
SUMMER II	Developmental and Educational Psychology	0	Psychological theories and research as related to the design and practice of education
	Second Language and Special Needs Learners	0	Seminar on second-language instructional theory and practice, and bilingual and ESL literacy and science instruction
ACADEMIC YEAR II	In-Classroom Internship	0	Team teaching with partner teacher in 9-12 science classroom
	Student Teaching		Student teaching in 9-12 classroom (7.5 wks)
	Analysis Seminar		Weekly seminar
	Capstone Teaching Performance Event		Praxis II State required exam



It Just Takes One

Science Outreach Programs
1972 – 2008
Physics Department
Auburn University

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Introduction

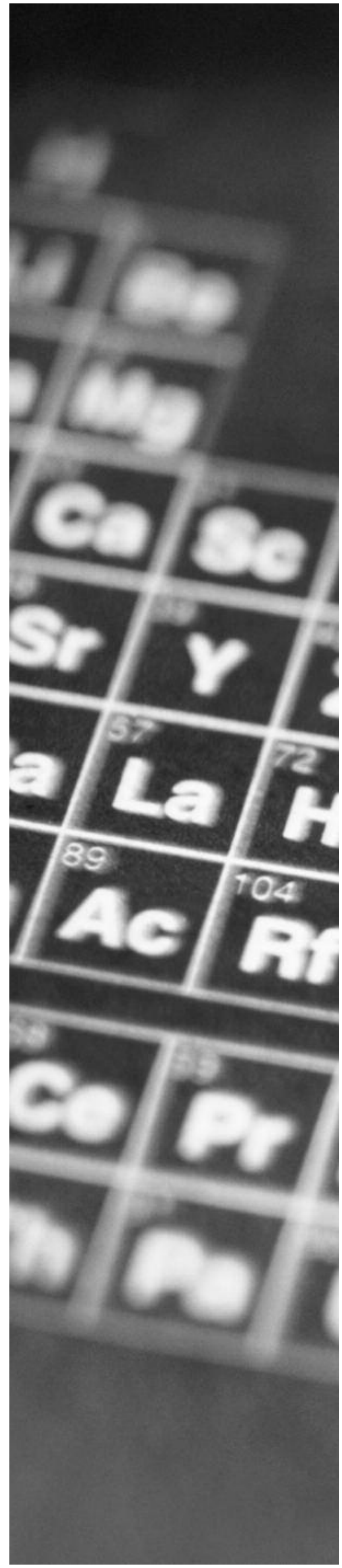
The purpose of this paper is to review high lights of the thirty-seven year Science Outreach Journey of one faculty member, to show that one person can contribute to and generate a considerable amount of outreach and also to demonstrate that such efforts are somewhat contagious.

Before starting, I would like to assure you that I am a full time faculty member in the Physics Department at Auburn University and I do not hold an Outreach Position. I routinely teach Fundamentals of Physics, College Physics, University Physics, Advanced Mechanics, Astronomy and manage the Undergraduate Laboratory Program. I do however, tend to get involved in time consuming Science Outreach activities during the summer months as a change in pace from the academic year.

List of Science Outreach Activities 1972 - 2008

The following consists of a fairly detailed list of outreach activities over the past thirty- seven years. The first column gives each project a number, the second provides a title and a one to five line description, the third provides funding information [I = internal funds, M = modest funds (<$100K), S = significant funding (>$100K) and PW = pays its way] and the fourth indicates a time interval.

No.	Title/Description	Funds	Time
1.	Science Fairs Local, Regional, State and National Students present projects University provides tours, activities, awards, hospitality rooms Soft sell, long range recruitment	I	1972 – 1990
2.	Chemistry and Physics Teachers Drive-In Conference Provides networking and support for content hungry, isolated science teachers frequently teaching out of field. Provides University with the opportunity to provide content and inject some contemporary science. Recruit by building a relationship with teachers	M	1973 – 1988
3.	Science Is Fun Presentation University goes to the classroom I'll take your classes for a day – but I'll need your help Demos/Scholarship Information/Careers/Recruiting		1976 – 1982
4.	Science Olympiad Local, Regional, State and National Activity based and something for everyone Generates excitement normally reserved for sports	M	1985 – Present
5.	Alabama Operation Physics (AOP) Alabama State Department of Education (ASDE) funds Summer Institutes/Professional Development for teachers Content based – learn science by doing science Fantastic network of outstanding teachers A social aspect is important	S	1988 – 2002
6.	Alabama Department of Economic and Community Affairs (ADECA) Industry funded AOP on Saturday during the academic year	M	1992 – 1996
7.	Alabama Operation Chemistry (AOC) Chemistry analogue to AOP (#5)	S	1993 – 2002
8.	Alabama Science In Motion Biology, Chemistry and Physics Lab program Professional development for teachers Summer and academic year training Largest mobile science project on the planet 33 vans and 33 exemplary science teachers on the road	S	1994 – Present
9.	Howard Hughes Science Outreach Initiative Designed to address the science pipeline problem Needs very creative staff A five year program that added 50 new students per year Eighth grade, Biology, Chemistry and Physics program 90% to College and 80% of those in the sciences	S	1995 – 2000



No.	Title/Description	Funds	Time
10.	Challenge of the Mind Partnership with 4-H and conducted at 4-H camp Week-end and Spring Break Science Camps for MS students	PW	1996 – 2000
11.	Youth Experiences in Science (YES) Started with pre-game mini-courses for MS students Show what the University is really about Initially funded by the Athletic Department Lots of spin-off and excellent PR	PW	1998 – Present
12.	Physics Invitational Would like to visit all schools with an AP Science Program Too many so have them come to us – but compete to be invited Competition, activities, scholarships awarded to schools Teacher becomes our recruiter	I	2000 – Present
13.	BEST Robotics Regional, State and National Very exciting and very Engineering oriented Replacing Science Fair and Science Olympiad at some schools	I	2000 – Present
14.	Goldstone Apple Valley Radio Telescope (GAVRT) Radio Telescope in NASA's deep space communication center Partnership – NASA, JPL, LCER and AU Students plan and conduct on line investigations using a RT	PW	2002 – Present
15.	Credit for Outreach Physics majors – 1 hr credit for planning, developing and conducting a science outreach project for MS students Science Education majors – 1 hr credit for planning, developing and conducting science show at regional high schools	I	2004
16.	AU Explore Like Physics Invitational (#12) but designed for middle school students	I	2005 – Present
17.	Department of Defense Education Activities (DoDEA) Replaced AOP (#5) Professional Development for science teachers at military base schools all over the world Programs grades 4 – 6, 7 – 8 and Physics (Modeling)	M	2005 – Present
18.	Team Science Partnership with 13 school systems in East Alabama to build the infrastructure needed to obtain an AMSTI (#20) award Sixty-five teachers worked with faculty for two weeks Funded by VP for Outreach and College of Science and Mathematics (COSAM) and School of Education Deans	I	2005 – 2007

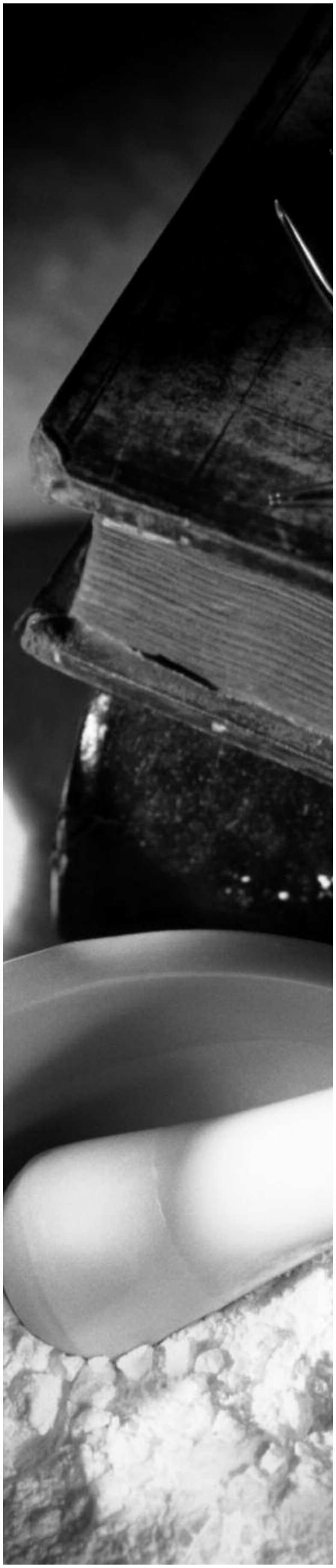
No.	Title/Description	Funds	Time
19.	AAPT – PTRA – Rural Teachers National program from professional organization Excellent leadership and materials Support for rural teachers who tend to be isolated and out of the mainstream of science education	M	2005 – 2008
20.	Alabama Math, Science and Technology Initiative (AMSTI) State-wide and modeled after ASIM K – 12 Science and Math (ASIM under umbrella of AMSTI)	S	2007 – Present
21.	Course Redesign FIPSE, NCAT and Course Redesign Form a partnership with HS Physics teachers Monitor preparation progress	I	2008 – Present

Reflections, Generalizations and Summary Statements

Since time and space will not allow for a detailed accounting of each of the above projects, I will reflect, generalize and summarize and then elaborate on one of the more significant projects, Alabama Science in Motion (#8).

1. Some activities are well known and supported by numerous institutions. It should be noted that a number of the above projects are annually carried out by faculty on numerous campuses and need no explanation. Among these are Science Fairs (#1) and The Science Olympiad (#4). While both programs have their merits, few institutions conduct both programs and many have replaced Science Fairs with the Science Olympiad. The Science Olympiad has more popular appeal, involves a larger percent of the student body and encourages team work. Another exciting, action packed related activity is the BEST Robotics (#13) competition. The reason for an institution to be involved in these activities is to encourage and support science activities at all grade levels. These activities bring students, teachers and parents to the campus and provide short and long term recruiting opportunities. It should be noted that an institution can become as involved as they wish with these activities since they provide local, regional, state and national competition.

2. Some activities are designed to get students on campus and involved in a dynamic science related activity. Like most other institutions, we have generated a number of activities designed specifically to get students on campus and involved in dynamic science related activities. These programs include the Howard Hughes Science Outreach Initiative (#9), Challenge of the Mind (#10), Youth Experiences in the Sciences (#11) and AU Explore (#16). AU Explore is a one day activity, Challenge of the Mind is a spring break activity, Youth Experiences in the Sciences range from half a day to a one week summer camp and the Howard Hughes Science Outreach initiative worked with students in an intense manner over a five year period of time. Participation ranges from as few as fifty (#11) to over one thousand (#16) students. Faculty involvement is as few as two (#11) to several faculty from each STEM department (#16). To be a success, strong support is needed at the department and college level and in some cases (#9) significant funding is needed. These programs provided faculty with the opportunity to do something really creative with interested pre-college age students. For example, students who participated in the Howard Hughes Science Outreach Initiative (# 9) synthesized a super conductor and determine the temperature at which it went superconducting, built a robot, programmed microprocessors, and participated



in a Chaos short course, etc. These programs provided excellent recruiting opportunities and directly addressed the science pipeline issue.

3. Good activities are designed such that everybody wins. Some of the programs simultaneously provide a win-win-win situation for students, teachers and the department. For example the Science Is Fun Presentation (#3), and the Physics Invitational (#12). Students benefit from a science experience and may be awarded a scholarship, teachers build a partnership with the department and the department creates a long-term recruitment rich relationship with teachers and schools.

4. Many programs are created specifically for teachers. Among our largest, strongest, and best funded programs are those that have been created specifically for teachers. Among these are the Chemistry and Physics Teachers Drive-In Conference (#2), Alabama Operation Physics (#5), Alabama Operation Chemistry (#7), Alabama Department of Economic and Community Affairs Workshops (#6), Science In Motion (#8), Goldstone Apple Valley Radio Telescope Project (#14), Department of Defense Education Activities (#17), Rural Teachers (#19) and Alabama Math, Science and Technology Initiative (#20). All of these projects are aimed at enhancing the science content knowledge of participating teachers, all have helped generate a teacher network, all have an academic year and a summer component, all are ongoing and/or have been replaced by a more significant program, all are well funded and each has grown to the point that additional staff are required to maintain them.

5. Some activities are created to accomplish a particular goal. Some projects are short lived and are created to accomplish a particular task such as the successful efforts of Team Science (#18). The purpose of this project was to partner with school systems in the East Alabama Regional In-service Region to obtain a multi-million dollar ongoing grant (AMSTI - #20) with the Alabama State Department of Education.

6. Outreach potential increased by partnerships. Many of our projects have been made possible as a result of our ability to partner with and share the vision of other organizations. For example Alabama Operation Physics (#5), Alabama Operation Chemistry (#7), Alabama Science in Motion (#8) and AMSTI (#20) are all the result of the relationship and trust we have developed with the Alabama State Department of Education. The ADECA Science Teachers Workshops (#6) were the result of a partnership with the Alabama Department of Economic and Community Affairs and Alabama based industry. Challenge of the Mind (#10) was made possible by a partnership with Alabama 4-H. BEST Robotics (#13) is the result of a partnership with the school of engineering, GAVRT (#14) is the result of a partnership with NASA, JPL and the Lewis Center for Educational Research (LCER). The DoDEA Summer Institutes (#17) are the result of a partnership with the Education branch of the Department of Defense.

7. Professional organizations provide outreach opportunities. Some outreach opportunities are the result of responding to requests for proposals (RFP). Alabama Operation Physics (#5) and Chemistry (#7) were created by our application to the National Operation physics and Chemistry effort. Institutions are invited to apply for a Howard Hughes grant (#9). We have applied for a Hughes grant three times and been awarded significant funds twice. We applied for and were awarded funds for the AAPT-PTRA-Rural teachers program (#19). Finally we applied to NCAT to be part of the Course Redesign project (#21).

8. Outreach projects generate other outreach projects. Some projects generate other projects. For example Alabama Operation Physics (#5) generated Alabama Operation Chemistry (#7) and the ADECA Science Teachers workshops (#6). Science in Motion (#8) and TEAM Science (#18) generated the Alabama Math Science and Technology Initiative (#20).

9. Projects can impact the learning and teaching environment of the department. One project (#21) is the result of the department trying to create a better learning and teaching environment. The National Center for Academic Transformation is working with the Physics Department at Auburn University to redesign the introductory Engineering Physics course. Part of this redesign process will allow us to work closely with secondary school Physics teachers to monitor their student's preparation and progress towards an engineering career. We will be working with secondary school Physics Teachers to help assure that their students are prepared for Engineering Physics.

10. Colleagues recognize the significance of science outreach and will contribute. Anyone reading the above list will readily conclude that this was not accomplished by one person. Department culture is usually a top down thing. The Auburn University Physics Department Head, Dr. Joseph D. Perez has made it know that science outreach activities are important to the short and long range well being of the Physics Department. As a result, when someone is asked to contribute, they usually respond in a positive manner. The home page for the College of Science and Mathematics (COSAM) Outreach lists six significant college level programs. The Physics Department created four of these, contributes a significant amount to the fifth and somewhat to the sixth. Several times during the year, a significant portion of the Department is involved in outreach efforts. This is a notable departure from the norm in several other COSAM departments – this is a result of the leadership and atmosphere created by the Department Head and perhaps somewhat to my smiling and never ending request for help.

Most Significant Project – Alabama Science in Motion

Next I would like to zoom in on what I consider to be our most significant project, Alabama Science in Motion (#8). The Alabama Science in Motion (ASIM) project is the largest mobile science outreach project on the planet. It is a statewide project, available to every public secondary school Biology, Chemistry and Physics teacher, impacts hundreds of teachers and thousands of students, has significant funding, has helped generate other projects and has changed the science teaching culture in both secondary and post secondary institutions of Alabama.

In order to serve all schools, the state has been divided into eleven in-service regions and each region is controlled by a state University. The following figure shows the eleven in-service regions and Auburn University serves region ten.

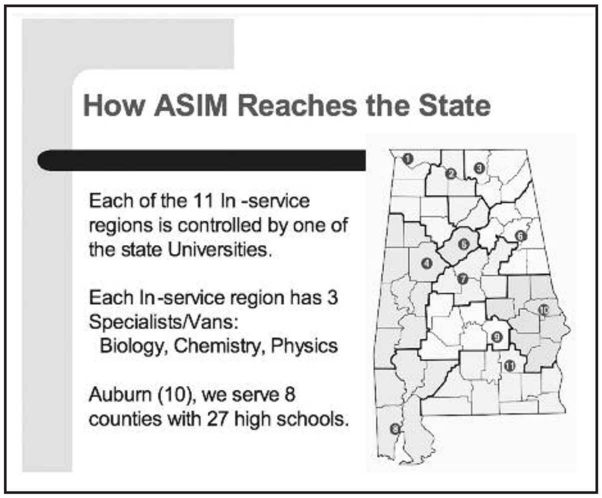


Figure 1. The entire state of Alabama is served by Science in Motion

Each of the eleven in-service sites has a director, three science specialists (Biology, Chemistry and Physics) and support staff (materials manager and administrative assistant). Each site has three vans (one for each discipline) that are used to deliver equipment to participating schools. This project is designed to do two things. First, provide professional development and subject matter content to participating teachers. Second, provide the laboratory component of the science classes offered at the secondary school level. Rather than each school struggle to purchase and maintain a mediocre set of equipment and labs, the project provides and maintains quality equipment which is then shared by a number of schools. The project provides and supports a core of statewide accepted experiments and also some optional more sophisticated experiments. Training and support is provided to all teachers on all equipment and for all experiments. The

figure below shows one of the 33 vans driven by the 33 exemplary science specialists to deliver equipment, materials and supplies to the schools of Alabama. The science specialists may just drop off the equipment, but more routinely stays at the school to provide support for the teacher and then may leave the equipment for additional work.

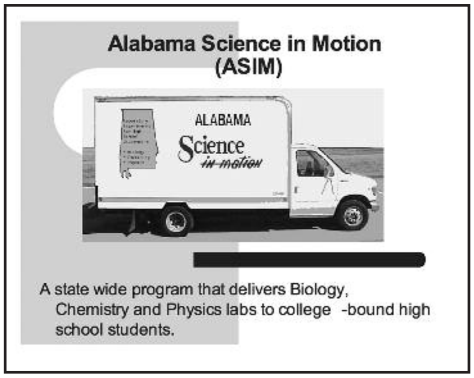


Figure 2. Thirty three Science in Motion vans are on the road.

Science in Motion was conceptualized in 1993 when two state legislators viewed an ABC News Video by Peter Jennings on World News Tonight about a Chemistry mobile science project of Juniata College. These Senators then worked with a number of science faculty to propose and pass legislation that created and continues to fund the project. Basically, the project is a line item in the budget of the Alabama State Department of Education. The wording of the legislation is such that if the project ceases to exist, the funds are terminated. As a result there is no motivation to terminate the project in order to scope up the funds for other projects.

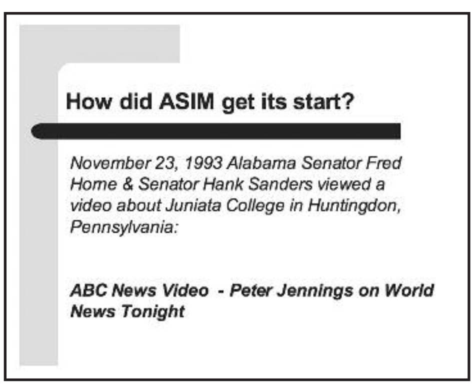
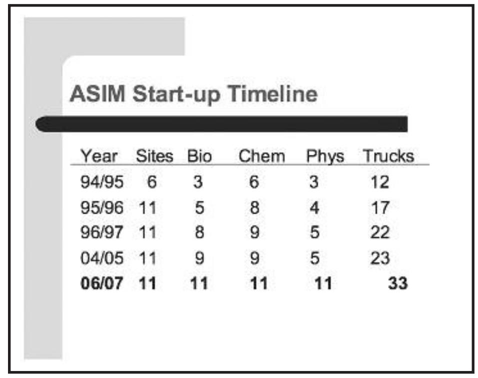


Figure 3. Science in Motion is the result of the vision of two state legislators and the work of secondary and post-secondary science educators of Alabama.

The figure below shows the project timeline and the rate at which science specialists and vans were brought on line. This figure also shows that the project has been well funded, enjoyed great success for over a decade and become part of the science education culture of the state of Alabama.



ASIM Start-up Timeline

Year	Sites	Bio	Chem	Phys	Trucks
94/95	6	3	6	3	12
95/96	11	5	8	4	17
96/97	11	8	9	5	22
04/05	11	9	9	5	23
06/07	**11**	**11**	**11**	**11**	**33**

Figure 4. Science in Motion is now fully operational with 33 vans, 33 science specialists and support staff.

Science in Motion has created a network of teachers and empowered them to collective do things they could not individually accomplish. For example it is a common occurrence for ASIM teachers to attend and participate in regional and national science teacher meetings. Also ASIM teachers have attracted a number of science teacher professional organizations and symposiums to our campus. Among these are the FLINN Science Teacher Workshops and the National meeting of Chemistry Teachers. The following figures show ASIM participants at the National Chemistry Teachers meeting and also at one of the FLINN workshops conducted by Steve Long, NSTA, HS Director. Without ASIM, these teachers would not have the support they need to accomplish these activities.

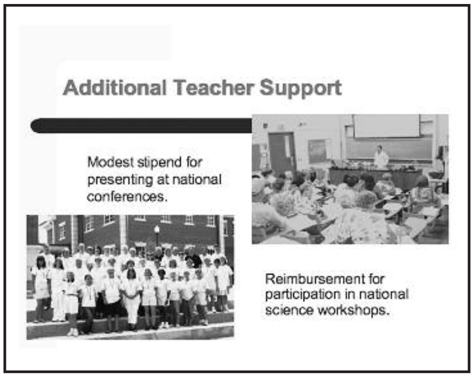


Figure 5. Science in Motion provides support and opportunities.

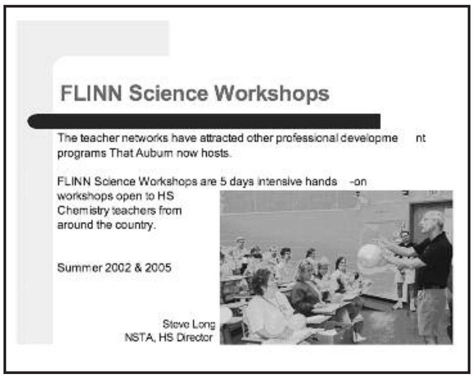


Figure 6. Science in Motion brings National Workshops to Alabama.

Science in Motion provides a better learning and teaching environment. While there are many goals and benefits of ASIM, the following slides sum up the essence of the program for students and teachers.

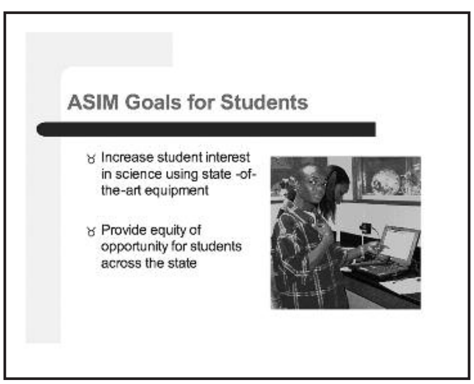


Figure 7. Science in Motion benefits all participating students, especially those in College Prep programs.

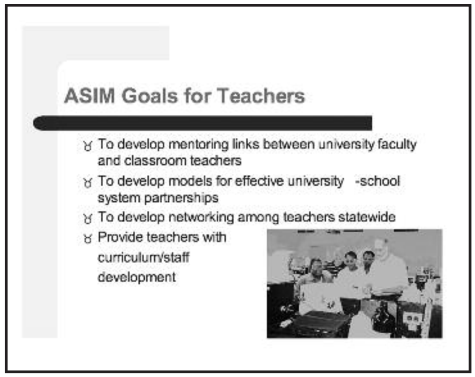


Figure 8. Science in Motion provides curriculum, equipment, materials, mentoring and opportunity.

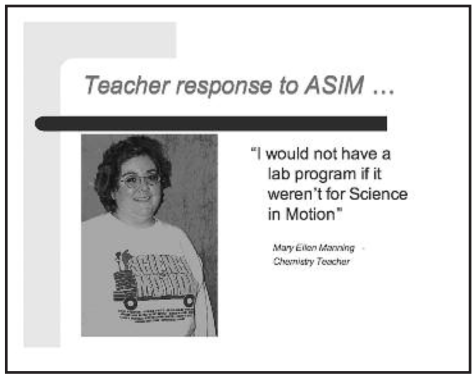


Figure 9. Science in Motion enhances the ability of outstanding teachers to be even better.

Finally, it's important to get a teacher perspective on ASIM. I consider the Alabama Science in Motion project to be our most significant project as a result of its impact on the state. As previously mentioned, it is available to every public secondary school Biology, Chemistry and Physics teacher. It provides a core of inquiry based activities and a selection of more sophisticated experiments. It provides academic year support and summer professional development. It is kept operational by a core of 33 exemplary Science Specialists and support staff. It has helped generate other significant science outreach projects. It has changed the science teaching culture of not only the secondary schools but also the states post secondary institutions. For example, once computers, interface devices and probe-ware became standard in the secondary schools, colleges and universities had no choice but to update. It is the largest and most significant mobile science project on the planet.

Lessons Learned

Finally, I would like to address the lessons learned from 37 years participation is science outreach. It is interesting to note that the lessons learned are essentially parallel to the generalizations given after the list of outreach activities. These are summarized below.

- It is essential that a major university have a science outreach component that includes a core of the widely accepted and expected programs.
- If well designed dynamic science opportunities are created and offered – students and teachers will come.
- A good science outreach activity is one that allows everyone to win.
- Science outreach activities may be designed to target students or teachers and occasionally both.
- Some outreach activities are short lived and are designed to accomplish a particular goal.
- An institutions outreach opportunities may be greatly enhanced by forming critical partnerships.
- Profession organizations occasionally generate a RFP for science outreach.
- Science outreach projects frequently suggest and/or generate another science outreach projects.
- Science outreach can improve the learning and teaching environment of the host department.
- Science outreach provides significant short and long term recruiting potential.
- Science outreach allows institutions to build a valuable relationship with science teachers at all levels.
- Department leadership defines the role of science outreach for the department and if creates a culture to support that role.
- With the help of colleagues, one person can create and sustain a significant amount of science outreach.

Thank You

Who Does Outreach and to Whom are They Reaching Out?

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Abstract

The scientific community wants the support of policy makers and the public, and the country needs a scientifically literate workforce and informed public. Outreach by scientists is an important component of accomplishing these goals. Federal policy encourages (and in some cases requires) outreach, but we need to examine who does outreach, what outreach is done and who is the audience for this outreach?

How Do Scientists Get Involved in Outreach?

Ramon Lopez elucidated a progression in the involvement of scientists in K-12 education. His scheme starts with *outreach* (which he defined as focusing on attitudinal changes), progresses to *education* (developing educational materials and participating in teacher professional development) and finally *reform* (involvement in wholesale change in the educational system). The intensity and intellectual commitment increases as a scientist moves through these stages.

Lopez’classification focused on K-12 education, and the nature“outreach”has changed significantly since he articulated this model in 2000. Outreach may involve K-12 education, but scientists are involved in activities that go beyond school walls to include science museums, lecture series, camps, writing and creating video for laypersons, and working with policy makers. Outreach is not limited to making attitudinal changes, but also focuses on improving participant content knowledge. We can broaden Lopez’progression of scientist involvement to outreach in general using *participant*, *director* and *reformer* stages.

- **Participant** is the entry level, usually involving one-time or yearly events in which the scientist has minimal responsibilities in terms of preparation and execution. Giving a lab tour to a group of visiting Girl Scouts, judging a science fair or speaking in a lecture series for the public are examples of this level of involvement.
- **Directors** initiate, organize and execute projects. They usually are motivated by a larger sense of purpose, such as increasing diversity or promoting a research field to policy makers. The size and intensity of the outreach effort grows, which often requires fundraising. External funding brings with it accountability and a much greater commitment of time and effort. This stage is often a turning point in a scientist’s career, requiring greater examination of the impact of his or her efforts, either due to externally imposed assessment requirements, or simply the need to balance his or her own priorities and time.
- Stepping into the **Reformer** role, in which the scientist becomes a national or international advocate for large-scale change, requires a conscious decision by the scientist to focus entirely on outreach. Nobel Laureates such as Leon Lederman, Carl Wieman and Russell Hulse who focus their efforts entirely on science education are notable examples; however, less-decorated scientists also take on this role.

Why Should Scientists Do Outreach?

There is fairly universal agreement on the ultimate goals of science outreach: maintaining international leadership and developing a scientifically literate public and capable workforce. Individual scientists have many motivations for becoming involved in outreach, including: having been a prior beneficiary of outreach and wanting to provide that transformative experience to others; enjoying working with people; finding self-fulfillment from participation; satisfying a sense of responsibility; or feeling a sense of (real or imagined) compulsion. The latter may arise from peer pressure or, more recently, research grant requirements.

The federal government, which provides a significant fraction of most scientists' research funding, believes that scientists should be active participants in outreach. The National Science Foundation, for example, mandates outreach as a significant component of research centers. The introduction of the NSF "broader impacts" criterion in the merit review process directs individual researchers to explicitly delineate the benefits of their research to communities outside their own. The common (although not necessarily correct) interpretation of broader impacts is that every scientist must have an "outreach project".

There are, however, disincentives for scientists to become engaged in outreach. The belief that commitment to anything other than research somehow diminishes a person as a scientist has lessened in recent years, but is far from extinct. Of more concern is the reward structure, which often doesn't know what to do with outreach. Outreach doesn't fit into the standard academic categories of research/teaching/service, so it ends up lumped in with service. There is an important distinction between outreach at the director or reform level (which requires intellectual effort, fundraising and leadership) and service, which usually means committee work or reviewing papers. Outreach at the participant level may be categorized as service; however, outreach at the higher levels certainly deserves its own category to recognize the unique skills it requires and to reward those who do it well.

Scientists at the participant level rarely question whether their efforts are worthwhile, probably because the time commitment is negligible. As a scientist's involvement grows, he or she has to struggle with balancing their time. The impact of outreach efforts is an important factor in balancing the research/teaching/outreach equation, but determining impact can be difficult. There are few outreach evaluation instruments analogous to the Force Concept Inventory (FCI) in physics. The FCI forced instructors to think about whether their students are learning what the instructors think they are teaching, and provided metrics that could be used to convince skeptics about the efficacy of interactive engagement techniques. Similar instruments are sorely needed to improve the quality of outreach and to convince others of its impact.

Who Should Do Outreach?

There is a common assumption that anyone can do outreach, even at the participant level. There are plenty of well-intentioned counterexamples. Just as some scientists are handy with instrumentation and others with computer code, some scientists have the talent and inclination to figure out how to explain complex concepts to laypersons. Others don't. A careful reading of the broader impacts criterion and the plethora of NSF-issued clarifications shows that they do recognize that scientists can contribute to broader impacts in different ways, most of which don't involve trying to explain quantum field theory to third graders. Outreach is one of many ways to have broader impacts, but not the only one. Scientists who feel they are being forced to do outreach shouldn't be doing outreach.

The other end of the spectrum is the professional for whom education and outreach are the primary job functions. For example, research centers have demanding enough requirements for outreach that many hire an education/outreach coordinator. Many large outreach projects have project managers or directors. Some people in these positions come from a science background, while others come from education or a combination of the two. They step into the'director' phase of involvement, some with limited experience at the participant level.

There are two issues related to the increase in the number of professional outreach positions. The first is removing scientists from outreach or limiting them to the participant level of development. While one may argue that this is an efficient use of scientist time, the lack of participation by scientists in outreach has implications for content and, more importantly, future leadership. Even if these positions are filled by scientists, the vast majority of professional outreach positions are not tenure eligible. Most are funded entirely on soft money and when the grant ends, so does the person's job and, sometimes, the institution's commitment to outreach.

A related question is what type of training those who do outreach should receive. What skills are valuable for outreach? Should all students receive some training in outreach, or just those that demonstrate talent and aptitude? Should we prepare scientists specifically for outreach careers, even though those careers may not have a clear career path? Is preparing science students for careers in outreach an appropriate part of a science department's mission or are other units better equipped for this task? Answering these questions requires looking carefully at the future of soft-money-funded outreach positions and at the reward structure for those who choose to make outreach part of their job responsibilities.

Who Should We Be Reaching?

Although many outreach efforts focus on K-12 education, outreach to other audiences and in other venues will become increasingly important as K-12 education becomes more and more constrained by standardized testing. The side effect of No Child Left Behind is a powerful and disturbing message to students that science is a body of unrelated facts that can be memorized and forgotten as soon as the test is passed.

What *do* people really need to know about science? Every major problem facing this country–from energy issues to the obesity epidemic–requires understanding math, science or engineering. While solutions are developed by scientists and engineers, everyone in the country is impacted. Citizens will be called upon to make important decisions personally and in the voting booth. They need to understand how science is done, what we can and cannot know, and how to use their knowledge of science to make decisions. Not knowing science puts individuals at a disadvantage. Science is a survival skill.

Should our goal be developing in the public an appreciation for the things we think are interesting, like black holes, nanotechnology, and the origins of the universe? Or is it more important for the average person to understand why internal combustion engines will never be energy efficient, why harmful chemicals are tolerated in water (or children's toys) as long as they are below certain concentrations, and how to understand food labels.

A certain segment of the population is predisposed to science. Margaret Wertheim analyzed the readership of eight popular science magazines and found that the 17 million primarily upper-middle-class white males 40 years and older who read them are very well served in terms of access to scientific information. What, she asked, about the 70 million readers of women's magazines?

Perhaps hers is a moot question because most people don't care about science anyway. Americans spend millions of dollars each year on music, video games, movies, sports and other forms of entertainment. Where we choose to spend our money reflects our personal priorities. Science is rarely among those priorities–even though none of the things mentioned above would be possible without science.

The problem, though, may not be that they are not interested in science. The problem is that we have not made enough of an effort to find out what science *does* interest them. There are literally millions of people in this country who are never going to care about the cosmological constant, but may be motivated to learn physics because they want to make animated movies or video games appear more realistic. Physicists may find Newtonian physics old news, but the reality is that NASCAR has more fans than string theory. We can wring our hands over this, or we can use it to capture the interest of kids that might not see why they should pay attention in school until they realize that you can't win races without science.

Reform

In research fields, goals and priorities are set by the community, and therein lies another issue for outreach. What is the "outreach community"? The sheer breadth of the field complicates forming such a community, even with electronic communication. People involved in outreach span disciplines, geographic regions, types of institutions and job titles. We don't go to common meetings where we can communicate with each other and most of us identify primarily with our research communities.

What outreach is important and who does it is set now by funding dicta. Although there are funding programs specifically for outreach, a large number of outreach efforts are funded as ancillaries to research grants. Might it be more effective to focus outreach resources on those institutions and people that have demonstrated themselves to be capable, instead of 'tacking-on' outreach to research grants? Is there any reason not to have a center of excellence in outreach the same way you would have a center of excellence in spintronics?

In thinking about the formation of an outreach community, we should consider the evolution of physics education research (PER) as a separate sub-discipline of physics. PER was founded by traditionally trained physics researchers who shifted their research from physical systems to people learning physics. They utilized research methods that maintained as much of the vocabulary and methods of physics research as possible, and tried to apply the same standards as other physics research subfields. The second generation of physics education researchers has been trained in physics education research per se (much like the previous generations of materials scientists were trained as physicists, chemists or engineers, but now many have formal materials science degrees). Physics education researchers are thriving at some institutions, but struggling at others. Those of us involved in outreach should examine lessons that might be learned from the PER community so that we can leverage successes and anticipate possible roadblocks.

A Scientist at the Racetrack

In 2006, I happened to channel-surf onto a group of cars rounding the corner of a racetrack. I was about to surf right past when one car crashed for what seemed to me to be absolutely no reason. My curiosity about what happened led me on a fascinating and ongoing journey that included learning about a totally different culture, writing a popular science book (*The Physics of NASCAR*), developing materials for K-12 teachers, maintaining a blog and learning how to "do media".

The journey started from nothing more than the desire to understand –the same desire that drives all scientists. A professor in graduate school called it "the pit bull gene"– the inability to let go of a question until you find an answer. As often happens, each answer raised more questions and the more I delved into the sport, the more I realized that there was significant potential for using motorsports as a tool for getting people interested in math and science. As one person told me after a presentation I gave, "If I had only realized that physics was really about racing, I would have paid more attention in class".

At the most fundamental level, the science involved in NASCAR is much of the same science we normally teach in physics and physical science courses. There's obviously kinematics, dynamics, circuits and thermodynamics, but there are even examples of more esoteric topics like Lenz' Law: there are embedded loops of wire in the track that receive locating signals from transponders in each car.

In addition to learning how the physics I've taught for years is applied in the real world, delving into the NASCAR world was a personal learning experience for me. I was reacquainted with how my students must feel when they start studying physics as I struggled to understand exactly what it meant for a racecar to "get loose because air was taken off its spoiler". I found excellent teachers who welcomed me into race shops and track garages. I made friends with people I would never have met in academia or at research conferences. From the Davidson college physics grad to the Stanford Aeronautics Ph.D. to the two-year-college-educated crew chief, literally thousands of people in NASCAR rely on math and science every day. They provide an entirely new way to counter the 'geek-in-a-labcoat' stereotype.

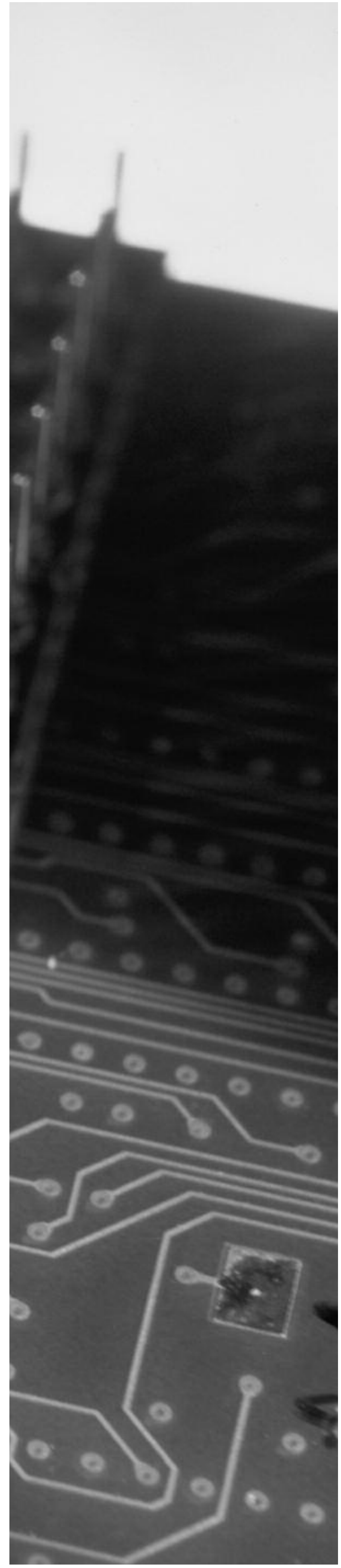
One of the benefits of outreach is that it can force you out of your comfort zone. In addition to meeting people who work for NASCAR, I wandered around the infield at race tracks where I talked to people who really want to understand why their driver wasn't running well.

Racing–like all sports–is rooted in passion. Seventy-five million people share a passion for NASCAR. The corresponding number for science is probably a little smaller. While it is hard to accept that not everyone is fascinated by the thing that makes you get up in the morning, why is it such a large step for scientists to reach out and use people's passion for sports and other activities to teach math and science?

We also need to examine new and developing ways of disseminating science and math. I started a weekly blog (www.stockcarscience.com/blog) that features commentary on weekly science-related events in NASCAR. One entry about a controversial missing oil-tank lid that had potential aerodynamic advantages drew over 22,000 hits. I make aperiodic appearances on the Sirius Speedway satellite radio program when topics arise that benefit from some scientific analysis. These are unique opportunities to show people that they really are interested in math and science—they just don't know it yet.

A big advantage of using NASCAR to teach science is that it directly relates to the world people experience. One NASCAR engineer told me, "I don't think we have any physicists working here: You guys think everything interesting is negligible". He was referring to air resistance and friction–the two things that determine how fast a race car can go. The traditional way we teach physics often bypasses what people actually experience.

The journey is not always been smooth. There is significant resistance from scientists to any model that challenges traditional ways of teaching. The concept of teaching science using NASCAR has met with comments ranging from "It's too complicated" to downright discriminatory statements like, "People who follow NASCAR fans aren't smart enough to understand science". I, with help from smart and dedicated colleagues, continue to work with schools, teachers, universities, science museums and NASCAR itself to prove these doubters wrong.



Conclusion

The current state of outreach is reminiscent of a city that has grown without any zoning laws. Outreach has been regarded as something that people do as a sideline; however, the power of outreach to shape the future demands that the scientific community give serious thought to how outreach should be funded, what type of outreach should be funded, who should do outreach and how (or if) we should prepare scientists for doing outreach. These dialogs need to expand the traditional view of outreach and consider the many news ways we can develop for getting more people interested in math, science and engineering.

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Telling a Story About the World That is Too Small to See

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Nanotechnology is an area of interest scientific and technological inquiry and it will have a profound impact on the lives of everyone. There has been significant investment of public and private money and virtually every academic institution has embraced nanotechnology as part of its research portfolio. In the United States, nanotechnology research and development was stimulated by the passage of the 21st Century Nanotechnology Research and Development Act. The authorization bill calls for almost four-billion dollars in spending among five of the 16 agencies including the National Science Foundation, Department of Energy, National Aeronautics and Space Administration, National Institute of Standards and Technology, and the Environmental Protection Agency. As part of this Congressional authorization and subsequent legislative actions the impact of nanotechnology on society has made a priority. Significant efforts have been supported to help understand and promote the public awareness of nanotechnology. The following will review the challenges and describe some of the remedies to these challenges.

Fundamental challenges to size and scale

One of the fundamental challenges in communicating discoveries in nanoscale science and engineering is the simple concept of scale. A grasp of scale is important when describing these discoveries to the general public especially if this effort is to successfully inform them how to distinguish reality from science fiction [2]. The simple authentication of imagery requires the observer to verify that an object at the proposed scale is even possible. Small mechanical devices that are purported to be at the atomic scale would be understood to be science fiction if the observer was cognizant of that particular scale. The behavior of mechanical devices at this size is a more complex issue, but for the purposes of creating a more scientifically literate public, the ability to scale is important.

Scale is used in a wide variety of scientific fields ranging from astronomy to nanotechnology. In all of these fields there is a need to project the observer to a scale that is far beyond their visual reach, referencing either significantly larger or in the case of nanotechnology significantly smaller units of measure. The question is what capability do most individuals have to project or embrace that scale and demonstrate a meaningful level of comprehension? Few studies have probed the ability of individuals to scale especially to smaller dimensions well beyond visual observation. Most of these efforts have focused on numerical estimations including the ability to estimate fractional populations. Estimating the scale of physical objects has mainly been explored with objects at a distance. The progression to a more complete understanding of the nanoscale may not be incremental or a result of some learning activity. More likely scientists gain an understanding of the nanoscale driven by an acceptance of inferential scientific data that over the past 100 years has laid the foundation for the field.

Few efforts have been reported to determine the ability of the general public to assess the differences in scale using objects. Most studies have focused on astronomy, the differences in scale between very large objects being assessed. Attempts to use analogies of the macroscales of astronomy to help understand the fundamentals of the nanoscale have been instructive but not highly educational [3].

Instead of objects, most of our understanding in the field of scale estimation involves the use of numbers. The ability to comprehend numbers over a large order of magnitudes and scale would seem to be an important element for appreciating the nanoscale and nanotechnology. The prefix nano is defined as one-billionth and a nanometer is therefore one-billionth of a meter. But can nonscientists embrace a billion or the more difficult term, one-billionth. The terms 'milli', 'micro' and 'nano' are not totally foreign but approximately 57% of the subjects could not accurately order these terms [4]. Previous efforts have demonstrated that many people are familiar with the term 'nano' but few define it with the precise definition of a prefix meaning 'one-billionth' [4].

Studies have demonstrated that individuals could order either '1,000,000,000' or 'billion' within the context of other numbers or text representations of these numbers [1]. When presented with a challenge of scaling the size of objects 10^8-fold most individuals were not successful. This is not surprising since the representation of two points over eight orders of magnitude is virtually impossible for most individuals to comprehend. Logarithmic scales ease the transition between macroscopic, microscopic and nanoscopic. While scientists are well versed and comfortable with the logarithmic scale, it is not a common aspect of everyday life [5]. Rarely do we have to scale more than one-thousand fold and make a comparison between 1 and 1,000 or more challenging 1 and 0.001 exactly. Move the scale to one-billion and the problem becomes even more challenging. The ability to estimate scale is a skill acquired with age and young children estimate with a tendency that appears to be logarithmic in function. This ability to scale evolves into a more linear approach over time and the range over which an individual can scale increases [6]. Underestimation or overestimation is a function of the magnitude of the number of objects being estimated [7]. There is a tendency for estimations to be more tightly clustered as the magnitude of the scaling effort becomes greater. In other words as the individual is asked to estimate the difference between two large (or small) numbers their estimates tend to cluster more closely as the number get bigger (or smaller).

The ability to comprehend differences in scale as a practical exercise is a skill also acquired with age. Work by DeLoache demonstrated that children up to approximately 30 months do not have a firm grasp on scale and view miniature objects as they would full-size objects [8, 9]. They attempt to interact with smaller scale objects as they might with the full-size object. Children were observed trying to get into a miniature car and to sit in a miniature chair. The ability of children to accept objects scaled much larger or much smaller than their real counterparts might in fact be an advantage in conceptualizing the nanoscale. Most toys are scaled down versions of their real counterparts, while conceptualizing the nanoscale requires a scaling up or the creation of 'macrotures' as compared to miniatures [10]. In the absence of the ability to scale, the discrimination between real and imaginary model representations becomes problematic. Side-by-side presentation of real and imaginary models can be confusing especially where neither portray an inherent size that is conveyed by the nature of the model.

Models

On the basis of the results obtained in a previous study, we believe it is possible to gain that reference point by the use of ball and stick models which most individuals recognize as an atomic-scale representation [1]. In the absence of an ability to scale, symbolism becomes an important route to convey concepts important to nanotechnology. The use of familiar representations of atomic-scale objects (atoms and molecules) immediately alerts the person that they are viewing something that is nanometer scale. While this might not convey an understandable absolute scale it puts the individual in the appropriate size-frame. The use of familiar symbols is a more obvious route than trying to introduce a new symbol with the accompanying interpretation with the hope that the individual will assimilate this new symbol and use it [9]. This is especially true in the informal science education venue where dwell time is low [11, 12]. Caution must be exercised in that scientists differ dramatically from the general public in their ability to comprehend symbols and this would tend to obscure the degree of obviousness in understanding a particular symbol [13].

Too Small to See

Informing the general public about nanotechnology is a challenge and these efforts compete for their attention with the greater array of entertainment options. Too Small to See is a five-thousand square foot traveling museum exhibition that opened in Fall, 2006 at Epcot, Walt Disney World Resort in Florida (Figure 3). The exhibit was based upon the four concepts:

- All things are made of atoms
- At the nanometer scale atoms are in constant motion
- Molecules have size and shape
- Molecules in the nanometer scale environment have unexpected properties.

The exhibition is a hands-on interactive event that leads the visitor from their own world into the nanometer scale one. Leading the visitors into the world that is too small to see is a series of exhibits that allow the visitor to see and experience scale leading them from the visible to the atomic scale. An effort was made to present every day objects including butterfly wings, dragon fly wings, computer chips and an oyster shell. Video kiosks tell the stories of nanotechnology provided by Earth and Sky (www.earthsky.org). All entrances then lead the visitor into a courtyard that represents a world which is enlarged one-hundred-million times. The enlargement factor was one of practical needs. The smallest object in the courtyard is an atom and that is approximately 2.5 inches to conform with concerns about choking of young children. Every representation in the court yard is atomic and ball and stick. In this fashion we hope that the visitor recognizes the size scale and appreciates that all things are made of atoms. The interactivity is gained by a series of exhibits where the visitor can build atomic models, move atoms and play with interactive digital displays of crystals and molecules. Summative evaluation has revealed that 60% of the visitors were interested in knowing more about nanotechnology as a result of the exhibits. Over 80% of the visitors surveyed altered their viewpoint of the smallest thing that they could think of from a macroscopic object to a nanoscale object after using the exhibits. The exhibit is on national tour where it has been seen by almost one-million visitors.

Nanooze

Nanooze was launched at www.nanooze.org in the Summer of 2005 to reach young people, advancing the excitement about discoveries in nanotechnology. Its mission is to excite, educate, and challenge kids age 6 to 10 years old and their teachers. Nanooze covers both the underlying science of nanotechnology and its applications. It has attracted a broad audience and has been one of the core resources to a number of national/international competitions, schools and after-school groups. Nanooze contains articles about nanotechnology, interviews with scientists, a blog about the latest discoveries in nanotechnology and even a nanotechnology game. It is translated into Spanish and Portuguese where it enjoys a robust following especially in Latin America. Surveys of readers reveal that over 50% thought that Nanooze was cool with approximately 21% stating that they visit Nanooze once a month. Nanooze has embarked on a number of initiatives to support various activities through special issues. During the 2006 FIRST Lego League competition, which Nanooze supported, 385,000 hits were recorded in one month indicating its broad reach. In 2007, it helped to support the First Lego League competition in nanotechnology by producing a special edition that contained information on a number of the

FLL topic areas. It also served as a resource to various teams providing answers to their questions.

In Summer, 2007 a print magazine was launched. It provided a ready 'retail' version of the web site. While web sites are a useful and simple means of distribution the competition for attention is fierce. Nanooze ranks among the top million web sites, but clearly it does not always stand out in the mass of internet sites. Further internet access for each student in every classroom is not the reality and use of the internet as part of an individual student's exploration during class is frequently problematic. The print edition of Nanooze gives teachers and students a window to the field and coupled to the web site a chance to learn more. Nanooze, the magazine first launched a special edition in support of Too Small to See and over 50,000 copies are being distributed during its tour. Now in Summer, 2008, Nanooze will produce a series of issues devoted to the five senses. The selection of this topic was based upon the interest that young people have in their own bodies and the inclusion of this subject in one of the first formal science teaching that most students are exposed to in the classroom. These will be available to teachers and students telling them about the nanometer-scale events that occur with our five senses and how nanotechnology is involved.

Lessons learned

The challenges of engaging the general public in the area of nanotechnology are significant. There is an equal set of challenges that scientists face when they engage in these activities. While significant 'talk' is given to the virtues of these activities by academic institutions, there is little substantial support either financially or professionally. The National Science Foundation has pioneered the notion that scientists need to be an active part of the broader impact that their work should have on the general public.

Intellectual merit

The inherent challenges of communicating with the general public about any emerging technology begins with an exploration into the current state of understanding. This is critical as it reflects the foundation on which a further understanding can be built. Sometimes this effort begins with a need to clarify misunderstandings which is frequently encountered especially when a technology emerges and there is no body of knowledge that is approachable by the general public.

Engaging the general public in matters of science is not an activity embraced by many scientists and those few that do often raise the ire of their colleagues. Work to establish the fundamental understanding of the general public with respect to a particular emerging technology is not viewed as scholarly work by hard core scientists likely because it resembles social science. As such the need to establish an important foundation upon which engagement can be built is frequently ignored and the engagement simply initiated. The result is a bad experience for everyone and the revelation by the scientists that the general public is not familiar with the endless jargon that frequently is associated with a given field. The important issue for the general public is 'what does this have to do with me?' and the impact is not always communicated effectively by the scientist to the public. In *Too Small to See* the general public was most interested in subjects that directly impacted their lives; stories about curing disease were the most popular.

Most of the fundamental concepts and scientific discoveries in *Too Small to See* and Nanooze are not the most current nor cutting edge. For the general public that is not familiar with the basics of nanotechnology, simple tangible documentation of the potential is powerful. One scientific breakthrough which attracts a great deal of attention is the 1989 work of Don Eigler and colleagues at IBM. Almost twenty years ago, these scientists moved a series of 35 atoms of the element xenon to spell out 'IBM'. Chronicled by a series of electron micrographs, these iconic images would become synonymous with nanotechnology and the potential to create things at the atomic scale. While the practical implications have yet to be realized the pictures and the story are a means to connect the general public with advances made at the atomic scale.

Conclusions

There are significant challenges to portray the nanometer scale world to the general public. Their foundation is not sufficient to allow them to fully embrace the scale but they do recognize a number of symbols that visually convey nanometer scale, notably ball and stick models. These models also convey shape and when used in certain media movement. Size, shape and movement are important concepts for understanding nanometer scale events. The ability to discern models that are a translation of scientific data as compared to fictional models is important. Public concern with the potential use of 'nanobots'and other submicroscopic agents needs to be informed by an understanding of what is possible and what is not. Representation of 'nanobots'as intricately machined objects portrayed in the same apparent size scale as a molecule of DNA need to be viewed as fictional. An informed public could potentially recognize a reference object as atomic-scale compared to one that is clearly not and appreciate the imagery as art rather than science.

Acknowledgements

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Reflections on the Conferences on K-12 Outreach: 2000 - 2008

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Introduction

The Science House, with the sponsorship of the Burroughs Wellcome Fund, has organized seven Conferences on K-12 since the first in 2000. Each Conference has explored ways in which scientists could support K-12 science and mathematics education. In the process we have brought together scientists and K-12 educators to discuss issues of concern, to show off programs that work and to listen to outstanding speakers contribute substantive ideas and examples. The Proceedings of the Conferences have been distributed in print and electronically. Articles from the Proceedings have been referenced in other publications. Copies have reached the IN boxes of deans, provosts, and chancellors. The distribution and impact of the Conferences have been much more than we envisioned.

As one of the scientists who has participated and learned I wish to review the Conferences and to reflect on themes that came from the Conferences as a whole.

The Conferences on K-12 Outreach from University Science Departments

The 2000 Conference, which had no specific theme, was highlighted by presentations from exemplary outreach programs based at other universities. It was here that I learned more about the Juniata College Science in Motion Program, it's offshoot the statewide Alabama Science in Motion Program, the Purdue School of Science K-12 Outreach and Rice University's partnership with the Houston Independent School District. These presentations emphasized nuts and bolts details about how to run year-round teacher professional development programs. The year-round feature was a relatively new idea then, but has become more common as we realize that teachers participating in year-round training programs are more likely to stay in the teaching profession. The Science House continues to operate year-round teacher support programs for rural school teachers, using ideas from the 2000 Conference.

A short presentation by Ramon Lopez titled "Science Education Reform and Roles for Scientists, Engineers and Their Organizations" provided a framework for many ideas about the place of scientists in K-12. This paper has probably been quoted more than any other paper in our Proceedings. It could be said that each of our Conferences has explored these roles.

The theme of the 2001 Conference was "Equity in Science Education" and we were fortunate to have speakers such as Jane Butler Kahle from NSF and Jack Rhoton from East Tennessee State discuss results from their research on equity issues. The Conference touched on several aspects of access to science and mathematics education, whether the inequities involved gender, race, or socio-economic status. Probably the most moving presentation was that of a graduate student, Kristy Dyer, "What You Don't Know Can Hurt You: Non-Logical Dimensions to Being a Woman Scientist."

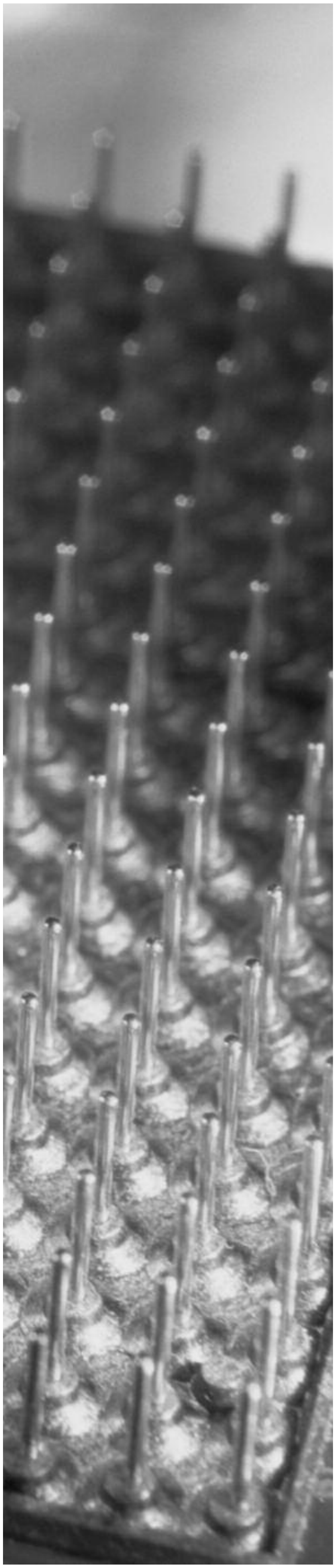
By 2002 we felt that the ongoing innovations in computing and the connections of schools to the Internet should be discussed with people who had been leading those innovations. We learned about simulations called Applets, about large scale electronic student assessments, and about using computer simulations to enhance student inquiry. We discussed how those innovations could be provided and maintained from the university and their impacts assessed. In the closing talk Donald Bitzer gave a charming description of the early history of the Plato project, a pioneering computer-assisted learning initiative. His talk showed the power of innovative ideas and how technology and pedagogy can be developed in tandem to aid student learning.

The 2003 Conference theme was "Linking the Science in the Classroom to the Science in the Laboratory." This was motivated by the programs of scientific research centers and organizations to inform the public about their research activities. Of course, NASA is well-known for its many programs that share the excitement of space with the public. Many other corporate and university programs do the same on smaller scales. This type of outreach can take the form of museum programs, research experiences for teachers and curriculum development that reaches the classroom. We saw several outstanding programs in each of those areas.

By 2004 many in our community were concerned with how universities could sustain outreach programs for the long run. It is one thing to operate an effective K-12 outreach program; it is another thing to nurture and grow the program after the three-year grant is completed. If one could reduce the comments of the speakers at this Conference, sustaining a program involves meeting real needs, measuring impacts, making strong external partnerships, being flexible, and becoming part of the core mission of the host institution (i.e., the university). That sentence overlooks the hard work and passion for their missions that each of the speakers displayed. This was the year of the snow storm that hung over the entire conference but never arrived in Raleigh.

So in 2005 we held the Conference in the Spring and also changed the format to include more interactions and discussions among the participants. There were fewer talks, more posters and panel responses, and a set of table discussions about how to start partnerships to address education challenges. The invited speakers talked about how No Child Left Behind would affect K-12 STEM education and how to assemble and maintain K-12 partnerships that included scientists. The participant discussions followed a structure that is recorded in the Proceedings. The structure is a useful starting point for any partnership considering working with K-12.

Then, finally, we reached 2008, the Proceedings that you are now reading. As you have seen, the 2008 speakers reviewed many topics about linking the university and its STEM faculty to the needs of local and state schools and to the larger populace. The speakers showed how a private research university can partner with a low achieving school district; how one faculty member's career can affect many K-12 teachers and students, how scientists should approach Broader Impacts; and how sophisticated scientific concepts, like "scale", require equally sophisticated education strategies. It is interesting to compare the 2008 strategies to those mentioned



in the previous conferences. The basics have not changed; they still work. Even though the K-12 STEM environment has changed.

Some Lessons Learned

What have I, as a scientist committed to supporting science education at all levels, learned from these Conferences? First, it is clear that K-12 science education is not a problem to be solved, it is a process that must continually seek improvement. We must discover and implement new and better teaching and learning strategies. We must develop new collaborations and institutions. We must execute our plans well. At the same time the K-12 students, their environment and the education demands of the greater society and economy are constantly changing. So yesterday's solutions may not solve today's problems. Scientists are used to solving a problem, writing the paper, and then going on to the next problem. K-12 STEM education will never be "solved." Nevertheless the process of improving education is an endeavor more critical than any scientific paper. This process is well worthy of our commitment.

Second, scientists who work with education must understand partnerships. In a partnership a group of people gather to address a common concern. Each member of the partnership brings his or her own objectives, talents and resources. No member has all the answers and everyone contributes to the thought and actions the lead to the common objective. Effective K-12 STEM education initiatives often involve scientists, university educators, K-12 teachers and administrators, and representatives of the government, community and business. Scientists bring to partnerships their deep knowledge and enthusiasm for science and the scientific process. This is an important contribution to any STEM education project. However, each other member of the partnership makes equally important contributions.

Third, it is amazing how the American K-12 STEM education landscape has changed in my lifetime and in the brief history of these Conferences. Several of the speakers referred to the advent of Sputnik as the event that motivated them, as it did me, toward a career in science or engineering. Oddly enough, US high school physics enrollments increased only slightly during the Sputnik era, then continued to decrease until 1983 when A Nation at Risk led off a series of reports about the depressing state of American science education.

It is popular today to refer to the *Rising Above the Gathering Storm* Report and *The World is Flat* as calls for all of us to reexamine our science/technology education pipeline, in particular in K-12. These reports and calls for action are not new, nor more compelling than A Nation At Risk was in 1983. The constant factor is that each generation must prepare and encourage the generation that follows. This is no less true in science disciplines than it is in families.

Since the 2000 Conference we have seen also the pervasive presence of the personal computer and the internet, which have changed how our students communicate, how they can learn and be assessed, and the entire character of information and knowledge. Even though a scientist may work at the forefront of the discipline, he or she was educated in a K-12 environment that no longer exists.

Fourth, universities have not resolved how they should interface with K-12 STEM education. As K-12 education has changed with time, so have the missions of the university campuses. As seen in the Conference Proceedings, some universities have made significant commitments to K-12 education. Some of these commitments have been sustained for long times; some have passed away. Some of the commitments come through the colleges of education and some through the sciences or engineering colleges. Some of the commitments have been institutionalized and some are based on the efforts of one "hero" who stepped out and led a program that passed away when the "hero" retired.

Calls for proposals for education grants quite often ask the question "How will this work be sustained after the conclusion of the grant period?" It appears that the university programs that have been sustained and continued have done so because they kept a clear sense of mission, made an effective contribution to K-12 education, actively partnered with other programs on- and off-campus, and aligned their activities with the mission and objectives of their university campus. These programs have nurtured activities, personnel and partnerships that involve many people and organizations. They have built a portfolio of capabilities so that they can contribute to K-12 STEM education in more than one way. They have measured and reported the impact of their work on K-12 students, teachers and classrooms. It is a constant struggle to maintain the activity and impact of any university-based K-12 STEM education program. We should remember that a "sustained" program is only "sustained" for now.

Future Conferences on K-12 Outreach

Where should the Conferences go from here? At this time our nation is finding its way through a struggling world economy. In the long run the US must adjust to continuing foreign competition from emerging economies that will someday surpass us. In order to create a competitive knowledge-based economy the US must improve the effectiveness of its education system, particularly in the STEM sector. In order to meet the hiring demands of the technology workplace we must assure that any student, regardless of race, socio-economic status or location, is encouraged to learn and can access a quality education.

Locally and nationally we do not have a clue how we can put enough qualified science teachers in high school classrooms. We are not even in complete agreement on what "qualified" means. As well, we have not agreed on what science a K-8 teacher should understand.

Technology has not been fully implemented into K-12 STEM education and indeed its impact and value are not completely understood. In their own domains scientists have dealt with education quality, access, globalization and technology. They have something to say and to learn about how these apply to K-12 STEM education. There are good reasons for future Conferences that bring together scientists and educators to discuss these issues.

About The Authors

Professor Carl A. Batt serves as co-director of the Nanobiotechnology Center (NBTC), and director of the Cornell University/Ludwig Institute for Cancer Research Partnership. He received his Ph.D. from Rutgers University in Food Science and has published over 120 peer-reviewed articles, book chapters and reviews.

Professor Batt has made important and tangible contributions toward educating both youth and teachers in Upstate New York in many areas of science. He has been involved in numerous K-12 science, technology, engineering and math outreach (STEM) activities, and as co-director of the Nanobiotechnology Center serves as the faculty mentor for all PSC educational programs, which span from pre-K through graduate education. Professor Batt, in collaboration with community partners, has established science clubs in three rural middle schools that are focused on getting young women excited about science, and also established two other "mixed gender" clubs that involve underrepresented minorities. During the summer, he is involved in running various research programs available for high school students, undergraduates and K-12 science teachers.

Dr. Batt has led collaborations of scientists and museum professionals in producing two interactive museum exhibitions *It's A Nano World* and *Too Small To See* that introduce children and their families to the wonders of the nano world that's too small to see with just your eyes. Recently many thousands of visitors toured *It's A Nano World* in a featured showing at Disney World in Florida.

Dr. Diandra L. Leslie-Pelecky, Professor of Physics at the University of Texas at Dallas, leads research that focuses on understanding the role of randomness and disorder in nanostructured magnetic material. But she has also led many activities in physics education and, recently, in bringing science to the public.

She has been involved in:

- Project Fulcrum, an NSF-funded GK-12 program that works with elementary and middle-school math and science teachers.
- The Workshop for New Physics and Astronomy Faculty, held at the American Center for Physics each fall and sponsored by AAPT/APS & AAS, which helps new faculty learn about balancing their research, teaching and outreach responsibilities.
- The 2007 University of Nebraska Conference on Communicating Science, Math and Engineering to Broader Audiences for researchers and communicators.
- The development of the Broader Impacts Toolbox, a work-in-progress resource to help researchers understand how to meet the requirements for NSF funding. The toolbox contains information on getting started, examples of good projects and hints for what not to do.
- Building SPEED (Science Partnerships: Education, Engagement and Diversity) is a forthcoming initiative to provide middle and high-school teachers with opportunities to research, and learn how to engage their students in science and math study via links to motorsports.

She is also the author of the recently published book "The Physics of NASCAR," in which she reveals "how and why drivers trust the engineering and science their teams literally build around them not only to get them across the finish line in first place, but also to keep them alive. Based on the author's extensive access to race shops, pit crews, crew chiefs and mechanics, this book traces the life cycle of a race car from behind the scenes at top race shops to the track."

Dr. Marllin Simon, Carr Professor of Physics at Auburn University, has in a long career, worked in almost every possible university-based science education outreach program. He has led numerous teacher-education programs, externally funded education projects, Science Olympiads, and summer teacher institutes and coordinated projects for the Alabama Science in Motion program. He has served as a consultant for several state Departments of Education and was the President of the Alabama Science Teachers Association. He has published laboratory manuals and developed new curricular pieces. He has often been an invited speaker at meetings of the American Physical Society and the American Association of Physics Teachers.

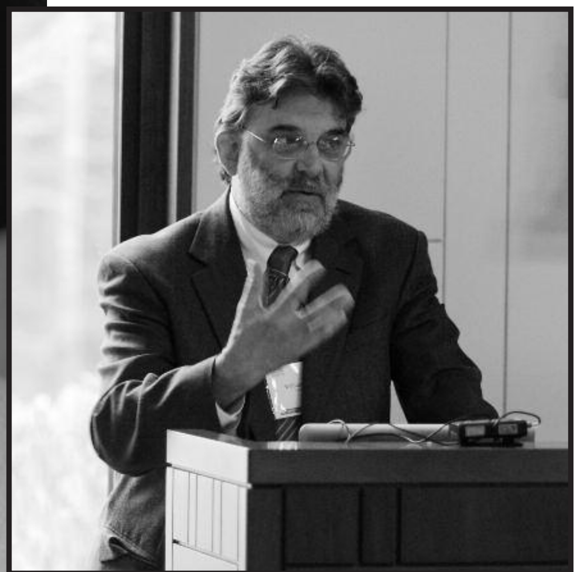
He was awarded the 1992 George B. Pegram Medal for Excellence in Physics Education by the Southeastern Section of the American Physical Society, and the Alabama Science Teachers "Friend Of Science Award".

Dr. Virginia L. Shepherd, Professor of Pathology and Medicine and Director of Science Education Outreach for Vanderbilt University Medical Center, received the American Society of Cell Biology's Bruce Alberts Award for Distinguished Contributions to Science Education.

The Center for Science Outreach was established in 2002 in order to promote and develop a strong relationship between the scientific and educational communities.

Current goals center around three main themes: creating in-classroom partnerships between scientists and teachers; developing virtual partnerships through the use of videoconferencing technology; and hosting in-residence teacher partners at VUMC. Outreach programs include bringing 7th through 12th grade students to the Vanderbilt campus for summer science camps and annual career days, helping parents get involved in their kids' schoolwork with science nights, and connecting scientists to K-12 classrooms through videoconferencing. In addition, the Center sponsors a variety of summer workshops focusing on inquiry-based instruction, science content, leadership, and technology.

Programs currently under development include the establishment of new degree programs for in-service teachers in order to enhance their science content background, and expansion and enhancement of our in-classroom and virtual partnerships.



Dr. William McCallum is a University Distinguished Professor of Mathematics and Director of the Institute for Mathematics and Education at the University of Arizona. In 1989 he joined the Harvard calculus consortium, and is the lead author of the consortium's multivariable calculus and college algebra texts. In 2005 he received the Director's Award for Distinguished Teaching Scholars from the National Science Foundation. His professional interests include arithmetical algebraic geometry and mathematics education. He has received grants and written articles, essays, and books in both areas.

The Institute for Mathematics and Education hosts numerous programs that link mathematicians to K-12. One example is the workshop Mathematicians in Mathematics Education which addresses the increasing demand for mathematicians who can constructively contribute to work in mathematics education, such as standards development, validation of tests, curriculum design, textbook review, and the preparation and professional development of teachers. This workshop orients mathematicians on key issues: the core mathematics of K–12, the mathematical knowledge of teachers, the nature of the educational system, the profusion of standards documents, the variety of curricula, and mathematics education research.

Dr. McCallum was unable to provide a manuscript of his presentation at the Conference.

Dr. David G. Haase is Alumni Distinguished Undergraduate Professor of Physics at North Carolina State University and the former Director of The Science House at North Carolina State University.

Dr. Sharon K. Schulze is the Director of The Science House and an Associate Faculty member of the Physics Department at North Carolina State University. She served as Associate Director of The Science House from 2003-2007. She manages the day-to-day operations, works with various grant-funded projects, and actively pursues collaborations and partnerships to improve K-12 STEM education in North Carolina and across the country. Dr. Schulze has high school classroom experience in physics and mathematics. A native Texan and graduate of Texas A&M University and the University of Pittsburgh, Dr. Schulze started her work in North Carolina at the North Carolina School of Science and Mathematics.

Abstracts of Poster Presentations

Rural Schools Equipment Loan Program

Gina Barrier and Janet Bailey
The Science House, NCSU

Established in 1991, The Science House is an educational outreach program of the College of Physical and Mathematical Sciences at NC State University with satellite offices across North Carolina. The poster focuses on the Rural Schools Equipment Loan Program of The Science House in which teachers in rural schools across NC are trained to use data-collection equipment that is then loaned to them throughout the school year. The Science House's programs, offered through the regional satellite offices, are described through a sustainable chemical reaction.

PD	**+**	**ST**	→	**PT**	**+**	**SD**
Professional Development	**+**	**Students and Teachers**		**Professional Teachers**	**+**	**Student Development**

This reaction involves developing quality professional development programs that meet the needs of hands-on inquiry-based learning techniques for teachers and students of science and mathematics. The reaction yields professionalism exhibited by teacher practice and shaped by educational research and the development of students' critical thinking and problem-solving abilities.

Kenan Fellows Program for Curriculum and Leadership Development

Valerie Brown-Schild and Susan Parry
The Kenan Fellows Program, NCSU

The Kenan Fellows Program for Curriculum and Leadership Development is a two year fellowship for public school teachers. The model is based on the premise that extended collaboration with researchers, coupled with highly focused professional development, intended to build curriculum design and organizational leadership skills, yields important results for schools challenged to meet the need for quality STEM education. Partnerships with scientists and engineers are structured to empower teachers and provide them with clearer perspective on their role in 21st Century student preparation, thus improving retention and engagement. Focus on the importance of leading in the design of quality lessons works to broadly energize instruction and build more positive student attitudes and performance in science, technology, engineering and math related fields.

Use of 3D Models to Show Structural Chemistry of DNA : For Sighted, Tactile, and VIB Learners

Susan Cady
Dept. of Chemistry, NCSU

Some students have difficulty visualizing flat text book figures in three dimensions. This is impossible for visually impaired and blind students. One solution is to provide an easy to construct three dimensional model. Several 3D models of symmetrical double helical DNA, made from beads and plastic canvas, are displayed at this poster. This model design shows many true chemical features of A-, B-, and Z-DNA, including left or right-handedness, number of base pairs per helix, and the direction of the anti-parallel strands using the gene sequence for the protein oxytocin. The features can be varied to adapt the level of chemical details to the appropriate grade level. These models are sturdy so blind and visually impaired students can feel the double helical shape, different beads representing nucleotides, and read the gene sequence on attached Braille letters. The teacher can display a DNA model in class while explaining the molecular features. Alternatively, students can make their own DNA model in several class periods or as an after school activity. "A 3D Model of Double Helical DNA Showing Variable Chemical Details", by Susan Cady in the Journal of Chemical Education, Vol. 82, January 2005, pp. 79-84.

Bringing Robotics into the Classroom

Jose D'Arruda
University of North Carolina Pembroke

As a teaching tool, robotics creates an environment that encourages students to: (1) Learn by inquiry and hands-on experimentation (2) Research and solve a real-world problem based on a Challenge (3) Learn how to write computer program which perform real-world tasks (4) Encouraging students to be designers and inventors (5) Build an autonomous robot using engineering concepts and (6) Present their research and solutions. We will discuss two programs which we are involved with using LEGO Mindstorm Robotic as a learning tool. One program involves over 300 middle school children who are actively learning science and the other involves a workshop for STEM teachers to be presented in June 2008. We believe that these activities could fundamentally change how students think about (and relate to) science, computers and computational ideas. Support for these programs comes from NSF and the North Carolina Space Grant Consortium.

Radio Astronomy at PARI: Real Science with Real Students

Elizabeth Snoke Harris
Pisgah Astronomical Research Institute

The Pisgah Astronomical Research Institute (PARI), a not-for-profit 501(c) (3) public foundation, was established in 1999 at the site of a former NASA facility southwest of Asheville, NC. PARI's mission is to provide research and educational opportunities for a broad cross-section of users in radio and optical astronomy and STEM disciplines.

Through outreach programs such as the School of Galactic Radio Astronomy (SGRA), Robotics: Opportunities for Building Outstanding Talent in the Sciences (ROBOTS), Duke Talent Identification Program (TIP) Field Studies, Space Science Lab (SSL) and the StarLab portable planetarium, PARI has made radio astronomy accessible to middle and high school students and teachers across the country. Each of these programs introduces students to the basics of scientific inquiry while increasing their enthusiasm and motivation to pursue careers in STEM fields.

The Imhotep Academy

Joyce Hilliard-Clark
The Science House, NC State University

Imhotep Academy, a pre-college program of The Science House, was started in the College of Physical and Mathematical Science at NC State University in October 1992. The mission of Imhotep Academy is to increase student awareness and enthusiasm for learning Science, Technology, Engineering and Mathematics (STEM) using hands-on learning activities and educational technologies strategies. The program is designed to guide middle school students toward high school college preparatory courses in science and mathematics using the NC Standard Course of Study as a framework. The goals are to:

- Expose students to and promote enthusiasm for mathematics, science and technology
- Strengthen academic abilities and prepare students for matriculation in the university.
- Provide multicultural experiences and academic enrichment activities.
- Teach about contributions of scientists and inventors of under-represented groups.
- Build self-confidence and self-esteem.

Students participate in Chemistry, Computer Technology and Physics laboratories, Mathematics and Statistics Classes, Marine, Earth and Atmospheric Sciences, Communications, educational field trips, cultural awareness experiences, and Internet exploration in six-day sessions. Theme-based instruction focuses on careers in areas such as Engineering, Forensic Science, Flight, Aeronautics, Astronomy, Chemistry, Biotechnology, Energy, Earth, Marine and Environmental Sciences.

The Algebra Program, started in June 2002, helps students and their parents recognize that mathematics is a powerful tool for making sense of the world by solving problems, modeling everyday numerical scenarios and to recognize that all students can learn Algebra. The program goals are to:

- Build skills and confidence in algebraic thinking and number reasoning.
- Discover the importance of mathematics and the connection to career choices.
- Solve algebra problems using games, math manipulative, computer technology and calculators.

Students develop a positive attitude for mathematics and sciences, improve their test scores, and learn real world applications from tours of various colleges on NC State's campus and local industries.

Students in grades 6-8 are enrolled in Imhotep Academy. The ethnic makeup of the students varies from session to session because students are registered on a first come first serve basis. There is an average of 64% African-American, 3% Hispanic, 2% Native American, 8% Asian/Pacific, 20% Caucasian, and 3% of the students describe themselves as 'other'. The students attending are generally 55% Female, and 45% Male, with the theme of each particular session impacting enrollment patterns.

Since 1998, we have enrolled nearly one thousand middle school students from across the state of North Carolina, with the majority of the student coming from Wake and the surrounding counties. Imhotep graduates are encouraged to participate in Photonics Xplorers, Photonics Leaders and other student programs offered at The Science House.

Photonics Leaders Program

Joyce Hilliard-Clark, David G. Haase, Pamela Gilchrist
The Science House, NCSU

Photonics Leaders is a year-round science and information technology program for tenth grade students from across North Carolina. The program goal is to guide and prepare minority students for success in STEM higher education programs and careers. Over three years, nearly 80 underrepresented students, including African-American, Hispanics and females, have participated in 300 hours of investigations and internships focused on electronics, optics, computer hardware and software at North Carolina State University and the Research Triangle Park. The program currently serves students from Durham, Guilford, Johnston, Harnett, Pitt, Robeson, and Wake County. The National Science Foundation funds the program.

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http://www.science-house.org/student/photonics/index.html)

Photonics Xplorers

Joyce Hilliard-Clark and Pamela Gilchrist
The Science House, NCSU

Photonics Xplorers is a year-round science, mathematics and technology program for rising ninth grade students from 17 North Carolina counties. The program goals are to improve students' competence and nurture their interest in science, research and related careers. In four years, 120 students underrepresented students, including African-American, Hispanic and females, have participated in 80 hours of hands-on learning focused on photonics (optics, electronics and laser technology), high school preparation, mathematics, scientific research, organizational, and presentational skills. The program is located at The Science House on Centennial Campus of North Carolina State University (NCSU) and is sponsored by the Burroughs Wellcome Fund.

Fun with Science

Dennis Johnson
The Science House, NCSU

The Fayetteville Satellite Office runs a K-12 math and science outreach program in Cumberland and the surrounding counties. The mission of the Fayetteville Satellite Office is to increase the use and effectiveness of hands-on learning strategies in math and science. With this mission in mind, the office provides support to elementary, middle, and high school's technology, content, and pedagogical training. Through a generous donation from Dupont content and pedagogy training has been offered through hands-on workshops in Bladen and Cumberland Counties. The teachers who have attended these workshops have learned new chemistry and physics concepts and how to teach them in a hands-on Inquiry method. This poster session is designed to provide an overview of the two year program, its objectives, and accomplishments.

Bennett's Millpond Environmental Learning Project

Colleen Karl
The Science House, NCSU - Northeast Satellite Office

The Northeast Regional Satellite Office of The Science House supports environmental education within the community to meet state curriculum goals. A Howard Hughes Medical Institute grant sponsors our work, which focuses on the development of teacher leadership, explores innovative educational technologies, and sustains student research projects. The Northeast coordinator conducts local and national workshops about community-based learning, Geographic Information Systems (GIS) and inquiry teaching. Since 2002, we have developed and sustained The Bennett's Millpond Project that brings together teams of local teachers and students to study the environment surrounding a historic millpond in Chowan County.

The Science House Jacksonville Office

Shawn Reintjes
The Science House, NCSU

The Jacksonville Outreach Office of The Science House at NC State University currently serves K-12 teachers and students in Onslow County and the surrounding counties of the southeastern region of North Carolina. The office provides professional development workshops for teachers in many areas including science laboratory safety, inquiry teaching and learning, and content specific workshops including meteorology, astronomy, and earth/environmental science. The office also offers workshop topics such as Infectious Diseases and Bioterrorism, Technological Design, Grant Writing and, Biology and the Internet. The Jacksonville office also participates in the Rural Schools Equipment Loan Program. The loan program provides laptop computers, graphing calculators, Vernier LabPro or Logger Lite software and various scientific probes for use in authentic data collection activities. This equipment is available for loan from the area outreach office to teachers within the service district at no cost to the participating schools. The Jacksonville office also works in partnership with area school districts on major grant projects. This satellite office of The Science House is currently partnering with Onslow County Schools and select NCSU faculty on a Math/Science Partnership Grant called E.N.V.I.S.I.O.N.S.

"What's living in your world?" Teaching Molecular Biotechnology to High School Students in a Research Context

John W. Stiller
East Carolina University

The science of biology often is viewed as a collection of important discoveries made by highly trained researchers, using nearly incomprehensible techniques. Recent and rapid advances in biotechnology only aggravate the problem by further distancing first-hand student experiences from the dominant methods employed by practicing researchers. Moreover, when molecular tools are introduced into basic biology classes, it tends to be in "canned" laboratories that do not provide a realistic understanding of the process of scientific inquiry. Given that many of the most common protocols in the modern molecular biologist's toolkit are available in easy-to-use kits, which require minimal training, the problem now can be rectified. A model learning experience, entitled "What's living in your world?", was developed through collaboration between a university researcher and high school teacher. Students sampled and identified microbial diversity present in their immediate environment using the polymerase chain reaction, DNA sequencing, and bioinformatics database searches. In our second iteration of this exercise, bacterial identification also was incorporated into a pre-existing lab on soil diversity, further illustrating the potential to use molecular tools in a high school setting. Our experiences provide a model for introducing biotechnology to high school students within a research-based context, and bridge the gap between scientific knowledge and process in the learning environment.

Reality Math - A Case Study Approach

Dorothy Sulock
UNC Ashevillie

Reality Math is a way of teaching math using case-studies about relevant or interesting subjects and developing the math as needed within real contexts. Reality Math is motivational, learner-driven, develops critical thinking, and improves reading skills. Reality Math uses the Internet, includes questions of the authority of information, is timely, is socially responsible, is context-centered, is synthetic, and is practical. Units range from Credit Cards, to March Madness, to Ecological Footprint, to Oil, to Nuclear Forces, and much more.

Optics Demonstrations for K-12 and Community Outreach

Kristin Walker and Choon How Gan
The University of North Carolina at Charlotte

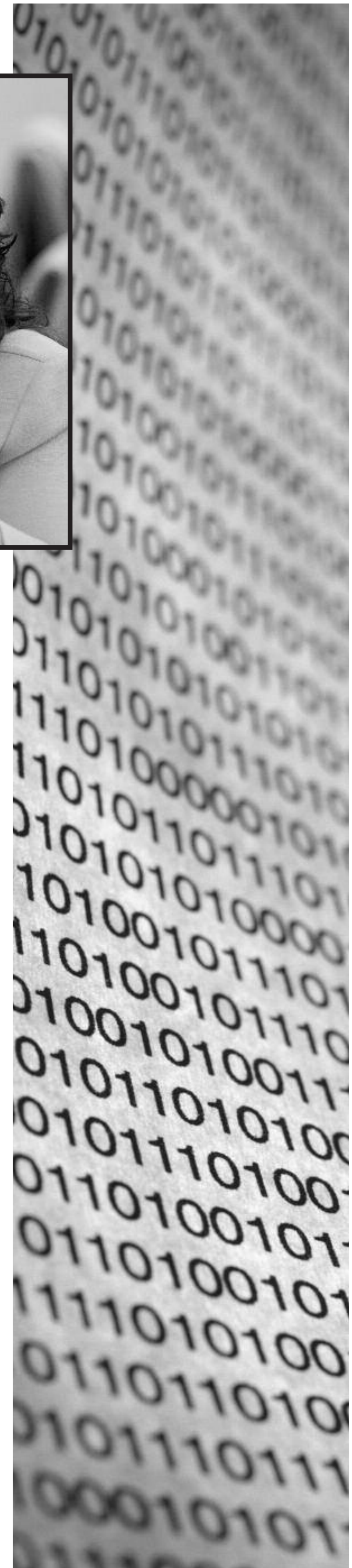
Interdisciplinary applications in the optics field are continually being developed. Introduction of optics to the K-12 generation is necessary to sustain this growth. As student chapters of the OSA and SPIE professional optics organizations at the University of North Carolina at Charlotte we are in the process of developing optics demonstrations for K-12 and community outreach. Our focus is to educate the greater community about optics and to promote optics as a career choice for students of all ages. Our two outreach events thus far have been targeted at high school students and community members. At these events there were several table-top experiments demonstrating optical phenomena requiring roughly 5-10 minutes per experiment. We will present some simple and fairly inexpensive demonstrations covering reflection and refraction, polarization, and fiber optics that are appropriate for all ages and feasible for many types of outreach activities.

Students Making Another Science Success Story (SMASSS)

Sandra L. White
Director, Center for Science, Math and Technology Education,
North Carolina Central University, Durham, NC

The Students Making Another Science Success Story (SMASSS) program, is a collaborative venture between Durham Public Schools and North Carolina Central University with a goal of increasing and sustaining the number of students

who are interested and competitively prepared to pursue college studies in the STEM areas. To achieve this goal, we have developed a multifaceted program, with the uniqueness of focusing on the same cohort of students from eight through tenth grade. We aim to: 1) *Stimulate a curiosity and bring focus to science while concurrently providing a foundation for understanding science and math in a select and diverse group of pre-8th grade students; and 2) : Insure that these same cohort of students have the comprehension of content, analytical and critical thinking capabilities to succeed and excel in the upper level of high school, which will provide the skills for college success.* **SMASSS** is a 3-year seamless program with an academic year component (Saturday Academy) and a summer camp component preceding 8th through 10th grade. The curriculum for each 3-week summer camp is inquiry-based, hands-on and emphasizes student learning by making connections between science and the daily lives of students. The first two summers students rotate through one week modules in life sciences, physical sciences and math/technology/computer science. The third year, a four week camp, allows the students to integrate the concepts they learn in biology, mathematics and chemistry by building an individual that can sustain itself in space. Curriculum materials integrate concepts across



disciplines and conform to the North Carolina Standard Course of Study. During the school year, weekly tutorials are provided in math, the 'gatekeeper' for the sciences. The Saturday Academies focus on field trips to varied science and research facilities as well as career awareness. Participants in the program represent more than twenty public and charter schools in the area, are equally divided between males and females and are approximately 92% African American, 4% Caucasian, 1.5 % Asian and 2.5% Other. Of significant note is that of the current 75 participants, 42% indicated at the beginning of the program, in a baseline survey, that they were moderately to very interested in science. After two years in the program that percentage is an amazing 92%. Seventy-five percent indicated that the program changed their feelings about learning science. Another objective parameter that is likely related to increased interest in science is the overall level of participation in science competitions. At the beginning of the program only 2.3% of the students had participated in a science competition other than a science fair and only 36% had participated in a science fair. The first year of the program we had 56% percent participate in the Eastern Region Science Decathlon (pilot events). As a result of this one exposure and five students placing in 1st , 2nd or 3rd place, the student's interest level increased significantly and in 2008, SMASSS sent four teams (6 students/team) of students to the Eastern Region Science Decathlon Conference in Charleston, SC. This resulted in two teams placing in five events and qualifying to compete in the National Science Decathlon, which will be held in May. Parental involvement is an integral component of this program. SMASSS is funded by the Burroughs Wellcome Fund SSEP Program and The American Honda Foundation.

Including Diversity in the Math Modeling Experience at UC Davis

Sarah A. Williams
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The Math Modeling Experience (MME) for undergraduates and high school students has operated for four years at the University of California, Davis. I launched the program as a graduate student in applied mathematics, and passed leadership of the program to other doctoral students when I graduated. The primary goal of the MME is to enrich students' interest in mathematics through challenging, hands-on problem-solving, culminating in the worldwide Mathematical Contest in Modeling.

Another goal of the MME is to host an inclusive mathematical community; in particular, we have encouraged participation of high school girls and students from under-served schools. By 2007, MME high school participants (35) were nearly 50% female and came from schools where free-or-reduced school lunch covers from 8% to 83% of the student body. This poster will give an overview of the MME, emphasizing successful strategies for recruiting and retaining girls and students from under-served high schools.

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