SCIENTISTS AND PUBLIC OUTREACH: PARTICIPATION, MOTIVATIONS, AND IMPEDIMENTS

Elisabeth Andrews Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder 80309-0216

Alex Weaver Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder 80309-0216

Daniel Hanley School of Education and Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado 80309-0216

Jeffrey Hovermill Shamatha Department of Mathematics and Statistics, Northern Arizona University, Flagstaff, AZ 86011

Ginger Melton Ethnography and Evaluation Research, Center to Advance Research and Teaching in the Social Sciences, University of Colorado, 580 UCB, Boulder 80309-0580

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Correspondence to: Ginger Melton, E&ER, CARTSS, 580 UCB, Boulder, CO 80309-0580 E-mail: ginger.melton@colorado.edu, 303-735-1563 (phone), 303-492-2154 (fax)

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ABSTRACT

Public funding agencies are increasingly requiring "broader impact" components in research grants. Concurrently, national educational leaders are calling for scientists to partner with educators to reform science education. Through the use of survey and interview data, our study examined the participation of researchers, faculty members, and graduate students from federal research laboratories and a Research I university, who were involved in K-12 and public outreach activities.

We found that scientists were often recruited into K-12 outreach activities by local departmental liaisons, colleagues, or professors. Scientists most frequently gave presentations, tutored, and organized or judged science fairs. Outreach participation varied by career stage, job type, and gender. The strongest motivating factors were a desire to contribute and enjoying their outreach experiences. For graduate students and researchers, a third motivating factor was the chance to improve their teaching and communication skills. Scientists of all types, however, viewed outreach as a form of volunteer work that was auxiliary to their other responsibilities. Time constraints due to other, higher priorities, the lower value placed on outreach by departments, and a lack of detailed information about outreach opportunities were significant barriers to participation. Even so, only a few scientists viewed their outreach experiences negatively, mostly due to classroom management, logistical, or organizational problems, or a lack of outreach skills.

INTRODUCTION

Outreach has been defined as "a meaningful and mutually beneficial collaboration with partners in education, business, public and social service. It represents that aspect of teaching that enables learning beyond the campus walls, that aspect of research that makes what we discover useful beyond the academic community, and that aspect of service that directly benefits the public" (Ray, 1999:25). Science outreach may include tutoring, mentoring, giving presentations or facilitating inquiry, supporting teachers, judging science fairs, developing resources and curricula, interacting with children or teachers in summer or after-school programs, and so forth.

Historically, outreach from universities to the public has been viewed parallel as important to a democratic society and the economy (Kezar, 2000, Boyer 1996). Today, there is a nation-wide call to realign university missions to fulfill their service duties to civil society (see for example Rice, 2003; Dyer, 1999; McGrath, 1999; Ray, 1999; Byrne, 1998; Votruba, 1996). Universities are being asked to practice what the late Ernest Boyer, former president of the Carnegie Foundation for the Advancement of Teaching, called the "scholarship of engagement" (Boyer, 1996). The scientific community, in particular, is being asked to participate in education reform. Leaders of the National Science Foundation and National Science Board call for scientists to help reform science and math education by engaging in "effective equal partnerships with K-12 schools" (Colwell and Kelly, 1999). Scientists are needed to help coordinate precollege and college-level academic requirements, assist with teacher preparation and professional development, develop instructional materials, and improve research on learning. They can serve in various roles, such as advocates, resources, or partners to students, teachers, schools of education, science centers, and advisory boards (Bybee and Morrow, 1998). Bruce Alberts, former president of the National Academy of Science, calls these partnerships "an important national priority" (Alberts, 1993). At the same time, public agencies that fund scientific research are increasingly requiring that researchers invest some of their funding in education or outreach activities that have a "broader impact" (NSF 2002; NSF 2001; NSF 1997; NASA, 1996). Research projects funded by NASA, for example, place "significant emphasis on delivering the benefit of [their] research endeavors to [their] public audiences" (Christian, 2003:31).

Even though many of the scientific societies and academies are already involved in public outreach (Rogers, 1981:36-37), and despite the national effort toward outreach and engagement, little is known about the public service or "outreach" mission of American universities (Dyer, 1999). The literature on scientists' involvement in outreach is even more sparse, and most of what is known comes from program descriptions (see for example Christian, 2003:31).

One form of outreach for which there is a growing body of literature that may provide insights into K-12 and public outreach is service learning (Eyler, 2000). In service learning, students learn and develop through active participation in thoughtfully organized service experiences that meet actual community needs and that are coordinated with a formal educational institution to address and support an academic curriculum (Colorado, 2003). A few studies have examined the motivations and obstacles that faculty experience regarding service learning (Driscoll 2000; Gyles and Eyler 1998). Some faculty members are motivated to incorporate service learning out of a sense of professional responsibility (Hammond, 1994), "…to apply their knowledge toward the betterment of society" (Holland, 1999:38). Others are motivated by the belief that service learning has a positive effect on student academic learning and personal growth (Abes et al., 2002; Holland, 1999; Hammond, 1994).

Factors that inhibit faculty involvement in service learning have also been described. In its annual survey of more than 900 institutions, Campus Compact (2002) reported that 64% of the

respondents cited time and faculty teaching loads as the greatest obstacles to integrating service learning into their courses. Time constraints include the time needed to create new activities, cultivate partnerships, organize logistics, and recruit students (Abes et al., 2002; Holland, 1999; Hammond, 1994). Difficulties of coordination and logistics are another deterrent (Abes et al., 2002; Holland, 1999). Recognition and rewards, especially in the tenure process, are also a problem (Holland, 1999; Hammond, 1994), although those with tenure are much less concerned about recognition and rewards than those without it (Abes et al., 2002). From these findings on service learning, we gain insight into issues to examine when studying outreach in general.

Our study examines the ways in which scientists are involved in outreach to K-12 schools and the general public and the factors that motivate or deter their participation. In particular, we look at the experiences of graduate students and faculty members at the University of Colorado at Boulder and of scientific researchers at nearby federal research laboratories. Our goal is to gain insight that will inform the activities of scientists, outreach educators, and funding agencies, and thus benefit the national effort to create the "engaged institution." This information will be of particular value to researchers and educators who seek to more effectively meet the new "broader impact" requirements of public funding agencies. Our study also makes several contributions to the outreach literature. First, it explores the broader topic of outreach rather than just service learning. Second, it examines the largely unexplored role of research scientists and graduate students in outreach and how their experiences and perspectives vary from those of faculty members. Third, it emphasizes scientists' involvement in K-12 outreach, a little-studied subject of critical importance.

METHODS

Both quantitative and qualitative data were collected for this study, through the use of written surveys and semi-structured interviews. Surveys were sent to approximately 325 scientists between late 1999 and mid-2000, before public funding agencies had begun to require that research have a "broader impact." The surveys included both fixed-response and open-ended qualitative questions. About 285 of the recipients were science graduate students at the same university, while the remaining surveys were sent to science faculty members and to research scientists employed at nearby federal research laboratories. Nine randomly selected science faculty members from the University of Colorado at Boulder, a Research I university, were chosen for the semi-structured interviews.

We received a total of 73 survey responses (24% response rate) from 48 graduate students, 13 research scientists (including 2 postdoctoral students), and 12 science faculty members. Since 88% of these voluntary respondents had been involved in science outreach at some point in their professional or educational careers, we shifted the focus of the study to examine their experiences rather than that of scientists in general. In this article, data from the scientists who had never been involved in outreach are omitted because the sample size of eleven was deemed too small to yield meaningful results. Of the respondents included in the study, 65% were currently doing outreach. Further research would help confirm our findings, as there might have been additional scientists who do outreach that did not return the survey.

Most of the graduate students came from the departments of chemistry and biochemistry (46%), geological sciences (26%), and atmospheric and ocean sciences (17%). The remaining few came from mathematics (7%) and physics (4%). The scientific researchers and faculty members worked in the same fields as the graduate students. The nine faculty members who were interviewed came from the chemistry and biochemistry and geological sciences departments at the university. Slightly under half of the respondents involved in outreach were women, which is an over-

representation relative to their participation in these disciplines; but only one interview subject was female.

All survey respondents were asked about their current and past participation in outreach to K-12 schools and the general public. In the survey, the quantitative questions assessed demographic information, the extent of respondents' participation and experience in science outreach at different stages of their careers, how they got involved in science outreach, and what motivated or prevented their participation in science outreach. A combination of quantitative and qualitative questions examined the respondents' reasons for doing outreach, their experiences, and their opinions about how to increase scientist participation in outreach.

The semi-structured interviews with faculty members examined their involvement and perspectives on science outreach; the factors that motivate or discourage their participation; the perceived attitudes toward outreach of their department, university, and funding agencies; and their perspectives on graduate students' participation in outreach. The interviews ranged from approximately 20 to 90 minutes in length. All of the interviews were audiotaped.

The quantitative data were tabulated and analyzed using descriptive statistics. The qualitative data, both from the surveys and interviews, were analyzed by identifying themes and using a form of thematic analysis that is more similar to a broad thematic analysis (Boyatzis, 1998) than to the more specific form of domain analysis (Spradley, 1980). The data were interrogated (Delamont, 1992) based on several primary questions about the motivations and barriers to participation in outreach and how to increase scientists' involvement in outreach.

INVOLVEMENT IN OUTREACH

In this section we explore how scientists were recruited into outreach, the frequency with which they participated, the types of outreach they did, and the time they spent on outreach activities.

Recruitment into outreach - Most scientists became involved in outreach through an institution-based outreach coordinator or through their connections with a colleague or professor (see Figure 1). Furthermore, 17% of researchers and faculty members indicated that their involvement began with a personal request to participate in outreach. Gender differences were found in graduate students' recruitment avenues. Many more male than female graduate students became involved through department liaisons or fellow students. In contrast, only female graduate students were recruited through community or science organizations. This gender difference was also apparent in the students' reports of recruitment as undergraduates where women more often became involved through organizations, while men became involved through fellow students. Both were recruited by professors. Recruitment avenues also varied by career stage. Most faculty and many researchers became involved via participation in their own children's education, while graduate students did not, probably because most of them did not have school-aged children.

Participation rates - Scientists' involvement in outreach varied by gender and career stage. Twice as many female (83%) than male (43%) graduate students had been involved in outreach as undergraduates. After entering graduate school, some of the women stopped participating in outreach while many men began to participate; during graduate school, 75% of the female respondents (18 respondents) and all of the male subjects (14 respondents) participated in outreach. Thus, female graduate students participated at a higher rate than expected based upon their representation in the sciences. Similarly, female researchers were much more likely to be involved

in outreach than their male counterparts. In contrast, male and female faculty members were more equally represented in science outreach based on their representation in the disciplines.

The rate of participation also varied among graduate students at different stages of their doctoral programs. Three-quarters of those currently involved in outreach had only one or two years remaining until graduation. We conjecture that, since these students have typically completed their coursework and examinations, they have fewer time constraints and competing responsibilities compared to students in the first two years of their Ph.D. programs, and thus have more flexibility to participate in outreach.

Types of outreach activities - The most frequently reported outreach activity for researchers, faculty members, and graduate students was giving presentations (see Figure 2). Scientists' outreach activities were also influenced by scientists' career stage and job type. Graduate students more frequently tutored than the other scientists; most of the graduate students also reported having tutored as undergraduates. Researchers more frequently mentored students and teachers and helped with teacher professional development than other scientists, and researchers were less likely to give presentations at work. Researchers and faculty members more often acted as a resource for school teachers than did graduate students.

Time spent on outreach activities - Graduate students spent, on average, 5.4 hours per month on outreach. Of these, two thirds spent 3-7 hours per month while the other third spent as few as 0.5 hours or as many as 15 hours per month. This estimate was uncorrelated with gender, seniority in graduate school (number of years to graduation) or field of study. Researchers recollected spending 7 hours per month on outreach when they were graduate students.

In contrast, two thirds of the faculty members reported spending 1-3 hours per month on outreach. The other third spent double that amount of time. However, the vast majority of faculty members said they would be more willing to participate in outreach if research showed that it was effective in increasing student knowledge and improving student attitudes toward science.

In summary, scientists were most often recruited into outreach through institution-based outreach coordinators or through colleagues and professors. Faculty, and to some extent researchers, often became involved in outreach to participate in their own children's education. Women participated more frequently than men in outreach activities as did graduate students in the last two years of their doctoral program. Scientists' outreach activities most often involved giving presentations, although role differences existed: graduate students more often tutored students, research scientists more frequently mentored students and teachers and helped with teacher professional development, and researchers and faculty more often served as a resource to teachers. Graduate students spent about 5.5 hours/month on outreach while most faculty members spent half that amount of time.

FACTORS THAT MOTIVATE SCIENTISTS' PARTICIPATION

The data presented in this section indicate that scientists at all career stages participate in outreach for similar reasons, but that subtle shifts occur in their motivations as scientists become more senior and their priorities change. The scientists' responses reflect initial motivating factors to become involved in outreach as well as factors that encourage their continued participation.

Rank order of motivating factors - Graduate students and researchers (reflecting back on their graduate school experiences) indicated that their top three motivating factors were, in decreasing

order of priority, "Desire to contribute," "Improve teaching skills," and "Fun/enjoyment." The complete list of responses is shown in Table 1, with the exception of a few write-in reasons such as "interest in the project," "interest in teaching," "community need," "curiosity," "[being a] female role model," and "convenience." The ranking of these factors was independent of students' gender. Similarly, faculty members indicated that their top two motivations for currently doing outreach were "Desire to contribute" and "Fun/enjoyment."

Desire to contribute - The "desire to contribute" was the greatest motivating factor for all the scientists in this study, whether graduate students, researchers (reflecting back on their graduate days), or faculty members. Many scientists wanted to help others by sharing their knowledge and enthusiasm for science:

> *I provided something to groups underrepresented in science that they might not otherwise be exposed to. (Graduate student)*
>
> *It's a good feeling when you've helped someone to understand and they're excited and interested in the material. (Graduate student)*

Researchers and faculty members often described their desire to increase students' appreciation for science as well as students' and teachers' science knowledge:

> *Science is a pretty exciting field. If one can explain that excitement to students in K-12, then some of them may then pick it up and make their own careers just on that basis. I think the hope that when you do these things is, some of them will think, "That is really interesting; I would like to follow that up."(Faculty member)*
>
> *It's generally not possible for a teacher at the grade school level to have depth of knowledge in a range of science subjects. I think the value in outreach is that we can help teachers fill the gaps in their own knowledge. (Researcher)*

Some were motivated by specific misconceptions held by the public:

> *If you look at public polls, for example the number of people who believe in young-Earth creationism, it is probably somewhere between 1/3 and 1/4 of the people—which you have to understand, it means they are practically rejecting everything that has ever been taught about science. (Faculty member)*

Other faculty members were more pragmatic, seeing outreach as a way to attract new scientists and new funding:

> *The more you can promote science, the better it is for the field, and the better it is for the sciences. … If you're educating people, you're also encouraging people to think positively about funding science federally, which is a major [expense]—millions of dollars goes into this. Closer to home, you can think of outreach as being important for direct funding at various levels. Like the university needs a new facility to do this, or a new building, or a new technology center. How are they going to get it? [The State of] Colorado isn't going to give you the money, so they have to go to private sources, so they need outreach. (Faculty member)*

Some researchers and faculty members spoke of scientists' responsibility to the public. Faculty members, as highly educated individuals, felt a sense of professional responsibility to share their knowledge for the betterment of society:

> *Outreach—when done correctly—is one of the most valuable contributions a professional scientist can make. (Researcher)*
>
> *I do science outreach, whether I am required to or not. I think it is part of my responsibility as a professional… I believe it is important. It's my professional duty. I enjoy it. I think it benefits society.*

> *I think it makes people more aware of the value of science. I think it get students ready to do more substantive things, and reason more quantitatively than they would otherwise. (Faculty member)*

Fun or enjoyment - Many of the scientists described their positive outreach experiences with statements that we categorized as "Fun or enjoyment." The graduate students and researchers (reflecting back to their graduate days) particularly enjoyed the activity of teaching science:

> *It was a fabulous experience. Kids were bursting with questions; they realized that science could be exciting and fun; they got to meet an everyday person (me) who does it on a day-to-day basis. (Graduate student)*

> *I enjoyed talking with school kids and adults about science; it made my occupation seem more relevant. (Researcher)*

When they described their "fun" outreach experiences, the graduate students most often mentioned a positive audience response. They described the students as "enthusiastic" or "interested" and described the experience as "fun," "great," or "neat." Virtually all of the graduate students and some of the researchers described students' responses to their outreach efforts, rather than the teachers' or other adults' reactions. These scientists' response suggests that the K-12 students' reaction was more important than that of the teachers; a negative response by a teacher could be tempered by students' enthusiasm, but the reverse was not true. By contrast, few faculty members discussed the students' response. Instead, faculty members took greatest pleasure in teaching science. Their enjoyment was less about having fun being with children than it was about sharing knowledge. Many scientists also found the experience personally rewarding in other ways, describing gains in recognition and increased confidence.

Improve teaching skills – Both graduate students and researchers (reflecting back to their graduate days) valued "developing a deeper understanding" of their subject area by having to explain the fundamentals of their field to a general audience. They also valued the opportunity to improve their teaching skills, including learning how to better share their knowledge with people of differing abilities and interests. Faculty members did not rate "improving teaching skills" as an important motivator for themselves. Nevertheless, they perceived it as important for graduate students who were going into teaching careers:

> *I would expect the Ph.D. students would be interested in [outreach], especially if they are considering going into the teaching profession later on. I would certainly encourage it for those that are going to go on to teaching positions, or intend to. I just think that they need to assure themselves that they like to interact with students, and that presenting their ideas in a way that can be understood by somebody with less education than them is really important. I wish I had had that experience when I was going to school. (Faculty member)*

> *Quite a few of them are thinking about careers in education in some form. This is sort of a way to get a little experience and see what is going on out in the world, to go and do a presentation—it is practice teaching. (Faculty member)*

Graduate students indicated that improving their teaching skills was indeed important at that point in their careers. Some students described gaining a range of skills:

> *I learned how to think differently about my area of expertise–in order to teach something, you often have to know how to explain it from many different angles and with different techniques. I gained many skills–public speaking, teaching, interpersonal–all worthwhile for many occupations. (Graduate student)*

Others mentioned specific skills:

> *Taught me quite a bit in preparing materials. (Graduate student)*

> *More experience performing in front of an audience. (Graduate student)*
>
> *Provided me with insight into misconceptions in the greater community. (Graduate student)*

Most of the faculty assumed that graduate students who would become researchers did not need any more teaching experience. Only one of the faculty members saw outreach as a means of developing skills valuable to a research scientist:

> *They realize that if they are going to go anywhere that they need to develop those communication skills as well as a basic science background. (Faculty member)*

To summarize, we found that the scientists in our study, who participated in outreach before a paradigm shift toward "the engaged institution" occurred, were involved in K-12 outreach for primarily intrinsic reasons, including a personal desire to contribute. They wanted to help improve students' and teachers' scientific knowledge and skills and to foster their interest in science. Another primary motivating factor was that the scientists, especially the graduate students and scientific researchers, had fun and enjoyed interacting with students, while faculty members enjoyed imparting their knowledge. The third factor that motivated graduate students and scientific researchers was the opportunity to improve their own teaching and communication skills, a more instrumental and less intrinsic factor.

FACTORS THAT HINDER SCIENTISTS' PARTICIPATION

The data presented in this section indicate that scientists at all career stages face similar barriers to participating in outreach, with subtle differences related to job role.

Rank order of hindering factors - Graduate students who participated in outreach, and researchers reflecting on their graduate school experiences, reported that the primary factors that prevented their involvement were (in decreasing order of priority) "Lack of time," "Lack of information about outreach opportunities," and "Lack of support from advisor or department." The complete list of responses is shown in Table 2, with the exception of a few write-in reasons: "poor organization," "lack of opportunities," "scheduling," "already teaching and financial concerns." The faculty members identified the same top two barriers to participation in outreach: "Lack of time" and "Lack of information about outreach opportunities." Similar to the other scientists, the third most limiting factor for them was "Lack of value to the department." A few faculty members wrote in additional reasons, including: "had no idea it was useful," "lack of high school student interest," "these activities are secondary to work."

Lack of Time - Time constraints were the unanimous primary impediment to scientists' involvement in outreach. Participants' availability to do outreach was limited by their other priorities, which were given precedence. All scientists felt it would be easier to participate in outreach if the time commitment was limited and/or flexible. In addition, the scientists, especially faculty members, stressed the importance of having an outreach coordinator to set up and coordinate outreach opportunities.

Time constraints were particularly apparent when students were asked about the value of outreach. Many responses of the graduate students involved in outreach fell into what we categorized as "Important, but…:"

> *I work a lot on my own research project, which is necessary because that's why I'm here – to do research and learn and get my degree. So time not doing that is time I'll need to spend in the end. (Graduate student)*

> *Highly important, but takes a back seat to research, thesis, and class deadlines. (Graduate student)*

Faculty members noted that graduate students' shortage of time for outreach is affected by financial obligations:

> *They have pretty busy schedules. Often they are being paid to do some research tasks or teaching tasks. They've got their own research thesis to do.... They don't necessarily have a couple of hours to prepare and give a lecture. (Faculty member)*

With regard to their own involvement in outreach, faculty members also experienced time constraints as a complex question of priorities:

> *People do [outreach] as much as they can…There is a real time limitation. If we don't get funding we lose our jobs. So if you had to raise half a million dollars a year from federal or private sources by writing twenty-five to fifty-page grants, each one of which takes a month and a half to write, how much time would you have to spend an afternoon here or there doing other things? (Faculty member)*

> *You've only got a certain amount of time, so if we're spending a lot of time at K-12, it means we're not putting that time into the undergraduates and the graduates—I don't think people are honest about this particular issue, because if you're going to put a lot of effort into outreach then someone is going to suffer. Either your own research is going to suffer, or your undergraduate teaching is going to suffer, or your graduate program is going to suffer. Assuming that you're not going to start working longer hours. (Faculty member)*

Lack of information about outreach opportunities - All scientists stated that they lacked information about outreach opportunities:

> *Opportunities need to be made more apparent. I think most grad students don't know what's possible – more outreach infrastructure might help facilitate this. (Graduate student)*

However, all the chemistry and geology graduate students had been included for some time on an e-mail listserve, through which they were sent e-mail messages at least once per month notifying them of a variety of outreach opportunities. Many of these students also worked within a research institute at the university that sent e-mail notices about outreach opportunities several times each semester; the opportunities were also listed on a web site. The students' responses suggest that most of these students did not read or remember those notices. Some students read the notices but wanted more information before becoming involved in an outreach program:

> *I've seen the e-mails, but I wasn't sure what I'd be getting into. (Graduate student)*

> *Sometimes I get an email saying mentors are wanted, but the goals, focus, purpose of the program are omitted (and these can vary drastically from program to program) – so I am unwilling to commit my time and energies to helping out. (Graduate student)*

Interestingly, these students did not respond by requesting more information about the program; instead, if the information was inadequate, they simply did not pursue the opportunity any further. It is evident that many scientists will not pursue an opportunity, even if it looks interesting, if it requires additional effort on their behalf. We suggest that they may also be fearful of making a larger commitment than desired. Instead, scientists are more willing to do outreach if the activities are clearly defined and coordinated by others:

> *It would be nice to have a central coordinated effort so that graduate students had an idea of what was needed. If I knew that a particular class or teacher had requested outreach involvement, I would be more likely to participate. (Graduate student)*

> *Outreach activities should come to scientists instead of scientists looking for them....It is very important for scientists to be asked directly by name to partake in outreach activities. (Researcher)*

> *If somebody like CIRES is organizing programs that bring in the clientele, I think our faculty and grad students would be glad to participate. But I think we are a small department that can't really take on those kinds of challenges. (Faculty member)*

Lack of value to the department - Many faculty members identified their primary job responsibilities as research and postsecondary teaching. They felt that outreach participation hindered their ability to fulfill those responsibilities and might be an ineffective use of their skills and time, and that it was not a valid use of their research funding:

> *It doesn't make money, which is what a research university is all about. Finding the time to do it is very difficult. You are paid to teach and number one you are paid to do research, because that is what brings in money. Outreach programs don't do anything for you—service doesn't get you a raise, basically. (Faculty member)*

Faculty members also pointed out the importance of having the university acknowledge outreach work in the tenure process. In keeping with this value system, faculty members at all career stages were unanimous in their belief that extensive outreach involvement was generally not possible or appropriate for untenured faculty:

> *You don't get tenure by having done some outreach. You get tenure for being an excellent teacher, and doing good research. I don't think we should really change that. When people get a little further in their career… then one can take another look at what we are doing. (Faculty member)*

Several faculty members described receiving implicit messages that they should become more involved in outreach, which they felt were unrealistic in the face of their time constraints:

> *The faculty are being asked to do more and more and more, and not only are we now expected to teach undergraduates and graduates, but there seems to be a growing expectation that we would now start to give more and more outreach and this is the "in" political thing.... (Faculty member)*

In contrast, others described receiving explicit messages about the importance of outreach, particularly through their funding agencies:

> *We get funded from the National Science Foundation and also from the Office of Naval Research. Mainly NSF, and they judge this [outreach] to be fairly important. (Faculty member)*

> *NASA has a very strong outreach program. They really care about it. They encourage…interaction, this kind of service, they kind of expect it. (Faculty member)*

Our study was carried out during a time when the environment for outreach was changing rapidly at research universities, and research scientists were becoming increasingly aware of new initiatives to promote outreach. None of our faculty respondents had yet encountered a situation in which their research funding, or that of a colleague, had depended upon their participation in an outreach program. Since that time, both NSF and NASA (one or both of which provided funding to all the faculty respondents) have changed their merit review criteria for research proposals to explicitly include outreach (NSF 2002; NSF 2001; NSF 1997; NASA, 1996).

Lack of support from advisors or department - Several students, and researchers reflecting back upon their graduate school experiences, mentioned that the lack of support from their department or advisor negatively affected their participation in science outreach. To some, a lack of explicit encouragement or support indicated that their advisors themselves simply did not value outreach or teaching:

> *Many more students would participate if their advisors made it known they were supportive or were involved themselves. (Graduate student)*

> *Departmental attitude towards grad students doing outreach is very important. Here I think it's perceived as a "waste of time" for grad students, not a duty to the community, or a fun departmental group activity, or a potential plus on the job market.…Feeling that this gets me perceived as being on the all-teaching-no-research track, i.e. being more interested in education than research, when in reality both are interesting to me. (Graduate student)*

Other students believed that their advisors wanted them to devote their time to research instead of other activities:

> *[I'm] having to do outreach work on the sly without advisor's consent. (Researcher)*

> *Not much support from my advisor—I wouldn't expect him to because he wants me to work on my research project, which is understandable. (Graduate student)*

The faculty members believed that their students had more important priorities than outreach, such as completing their research and other degree requirements. The faculty members were pessimistic about extensive involvement in outreach by graduate students. Their primary criterion for suitable outreach activities for graduate students was a limited time commitment. For example, judging science fairs was frequently mentioned as an appropriate outreach activity for graduate students; other activities included short presentations for K-12 students, a field trip, a lecture, or mentoring high school students in science projects. One faculty member described this conflict in detail:

> *A graduate student has to be effective and they have to take courses. Graduate courses, in general, in the sciences are pretty tough, and they have to put in time for research. If they do judge a science fair or visit a high school on occasion that's one thing, and obviously I'm very much for that. But if they take on another [outreach] job, which is mentally very important and occupies them a lot, then I don't think it is a good idea....And that is like doing two Ph.D. theses in parallel. I see how much emotional time and thinking time it takes, on my part. I'm in a stage in my career where I think I can do that. But not graduate students. (Faculty member)*

Very few of the faculty members explicitly discussed the subject of outreach with their students. Although they generally did not explicitly discourage their graduate students from participating in outreach programs, most never discussed the topic with their students at all:

> *I think we probably don't do a very good job in that area. I don't think the graduate students are really very well informed about any outreach that goes on here unless …their advisor…is doing some outreach. By and large I don't think the students here know much about it. (Faculty member)*

This lack of discussion about outreach led the graduate students to believe that there was a lack of interest and involvement in outreach by the faculty. Interestingly, it also led faculty to believe the same about graduate students. Several faculty members felt that they valued outreach more than did their graduate students, and that some students resisted participation:

> *Their minds are filled with going to class, getting homework done, and then doing all of the research they have to do here, and they are pretty stressed out. They are not looking for something extra.… Most of them don't have a lot of extra time, or probably not the inclination…unless I required it. Which I haven't done. (Faculty member)*

> *Not interested. There are these people who really in the end would rather be in the lab doing science and not out trying to communicate what they do, or hear about other people's situations or problems. That is just a difference in personality. (Faculty member)*

In summary, our study found that time constraints due to scientists having other, higher, priorities are the greatest barrier to participation in outreach. Scientists are concerned with taking too much time away from research obligations, especially if their efforts are spent coordinating outreach efforts rather than sharing their expertise. Scientists preferred to have flexible and limited time commitments in their outreach obligations. The second major impediment was the scientists'

need for specific information about potential outreach activities, of the type that outreach coordinators could provide. The third greatest barrier for faculty was the inadequate value placed on outreach efforts by their colleagues, and department, including the lack of recognition and rewards, especially in the tenure process. Graduate students also reported, as their greatest barrier, a lack of support from their advisor or department. This lack of communication, led both faculty and graduate students to believe the other group did not value outreach, even though a rough estimate based upon this study suggests that at least 20% of the scientists at this university do outreach.

POST-OUTREACH PERSPECTIVES

Graduate students and researchers in our study were asked whether their outlook on outreach changed as a result of their experiences. Half of the scientists reported no change, having apparently had realistic expectations about outreach:

> *I knew from the beginning that it would be time-consuming, yet fun and rewarding. (Researcher)*

One-third reported a positive change:

> *Kids usually were much more inquisitive and less cynical than I had expected. We see so many negative media images about "kids these days" that it's easy to forget that kids are still kids. (Graduate student)*
>
> *Almost all of my outreach activities have been rewarding and make me feel that studying science is a valuable career. It helped me to get more excited about my own research. (Researcher)*

A few scientists (10%) reported a negative change in their perspectives toward outreach. Factors that left a negative impression included classroom management problems, poor audience responses, a lack of necessary skills to do outreach well, and logistical, organizational, or scientific problems during the activity:

> *The kids weren't really interested in more than the demos. I also have a hard time keeping them in line. (Graduate student)*
>
> *I felt that the teachers inviting us to participate in outreach had much less direction and advice to give than I expected. They seemed to have no clear idea of what they wanted me to accomplish, which made it more difficult for me to tailor my efforts to their classroom. (Researcher)*
>
> *Too many kids per graduate student. (Graduate student)*

Graduate students also mentioned the negative effect of inadequate recognition for their time and effort:

> *The presenters were not treated as if we were contributing anything at all. Some respect for the work that went into our effort would have been appreciated. (Graduate student)*

In summary, for almost all respondents, the outreach experience either met the scientists' expectations or positively impressed them. Only 10% of scientists viewed their outreach experience negatively. Scientists are not skilled in classroom management (for the most part), and several scientists cited having to deal with unruly students as a primary problem in doing outreach. Perhaps these challenges, along with organizational and logistical issues, could have been reduced with training and support, such as from an outreach coordinator, or with greater clarification of the teacher's role in managing the classroom.

DISCUSSION

Our study makes important contributions to the small body of literature pertaining to science and outreach, and provides valuable information for scientists, educators, coordinators, and agencies involved in or concerned with outreach.

Involvement in Outreach

Our results, based on scientists' outreach activities prior to the "broader impact" movement, show both career stage and role differences in scientists' participation in outreach. Among graduate students, those toward the end of their doctoral education were the most likely to participate in outreach. Graduate students spent about five hours per month in outreach activities, typically giving scientific presentations, both on and off campus, or tutoring K-12 students. Other institutions have also reported that tutoring is the most common type of on-campus outreach (Campus Compact, 2003). Faculty members spent about half as much time as graduate students on outreach activities, giving presentations, both on and off campus, or acting as a resource for teachers. Researchers spent most of their time giving presentations away from work although they also commonly mentored students and teachers, helped with teacher professional development or acted as a school resource.

We also found gender differences in outreach participation. Both female graduate students and researchers were involved in outreach at a higher rate than their male counterparts, as other research has found (Surdyk and Diddams, 1999). Abes and colleagues (2002) also found a gender difference among faculty involved in service learning, where more women than men are involved in service learning, which contrasted with what we learned with our limited sample of faculty members. In another study that had somewhat different findings than ours, community and science organizations appeared to be effective in recruiting female graduate and undergraduate students, but completely ineffective in recruiting male students (Gwynne 1989).

Almost two-thirds of the scientists in our study became involved in outreach through an institution-based outreach coordinator or a colleague or professor. Similarly, Abes and colleagues (2002) found that faculty were successfully encouraged into service learning via another faculty member, community member, or student. Other research has reported personal contact between the recruiter and the prospective volunteer as the most influential recruitment strategy (Davis, 2000; Green et al., 1984). Both our study and Wier's (1991) found that scientists with children were also recruited to help as scientist-parents in their children's schools. The least useful recruiting strategy involved anonymous tactics, as other research has also found (Wier 1991).

Factors that Motivate Scientists' Participation

The greatest motivating factor for the scientists in our study, like the altruistic participants studied by Etzkowitz and Alonzo (1995), was a desire to contribute. This motivation fits Holland's (1999:38) description of "early adopters"—that is, faculty who became become involved in outreach for primarily intrinsic reasons during the time when their universities regard research duties as paramount. Similar to the scientists in Wier's (1991) study, our participants wanted to help encourage students' and teachers' scientific knowledge and skills and interest in science as well as help increase science literacy, correct misconceptions about science, and contribute to the public's view of the value of publicly funded science. As highly educated individuals, our scientists felt a social responsibility to share their knowledge for the betterment of society, as research on outreach and service learning has shown (Holland, 1999; Hammond, 1994).

The scientists also wanted to know if their efforts were effective in increasing student knowledge and improving student attitudes toward science. This result is congruent with other science faculty members' motivations for doing outreach (Wier, 1991). Osguthorpe and Patterson

(1998) note that scientist participants need to know they are making a difference and to have their contributions valued. For example, an evaluation of a Rockefeller University outreach program found that scientists valued feedback from teachers indicating that the high school students were operating above expectations (Kaiser, 1996). Non-science faculty involved in outreach and service learning also report being more motivated to participate in outreach if their efforts facilitate student learning (Abes et al., 2002; Holland, 1999; Hammond, 1994).

The second strongest motivating factor we found was the fun and enjoyment experienced by the scientists during their outreach activities, which reinforced their desire to continue to participate, as others have also found (Falk and Drayton, 1997; Wier, 1991). The enjoyment experienced by faculty members took the form of pleasure in sharing knowledge. In contrast, most graduate students and researchers particularly enjoyed the positive responses of K-12 students to their activities. Furthermore, as some of our researchers and those in other studies have indicated, working with broader scientific topics and having a direct impact on the "real world" (i.e., real children and teachers) was an invigorating and refreshing experience for scientists (Falk and Drayton, 1997; Wier, 1991).

The third most common motivation to participate in outreach was, for graduate students and researchers, the chance to improve their teaching and communication skills, which others have also reported (Weaver et al., 2000; Jacobson and McDuff, 1998; Bruce et al., 1997; Falk and Drayton, 1997; Milliman, 1996). For example, undergraduate physics majors strengthened their own content knowledge and found additional uses for their knowledge (Bruce et al., 1997). Faculty members could also benefit from outreach in this way, if they observe pedagogical methods such as inquiry-based learning in the classroom and learn how to apply these methods in their own courses (Alper, 1994). Having the opportunity to enhance these skills is more of an external, non-altruistic, motivator. Research has shown the promise of such benefit to be important in recruiting volunteers, recommending the experience to others, and an overall positive evaluation of the experience (Green et al., 1984).

Factors that Hinder Scientists' Participation

Our study, like several others, shows that time constraints to be the greatest barrier to participation in outreach and service learning (Abes et al., 2002; Campus Compact, 2002; Hammond, 1994; Holland, 1999). These time constraints, however, were defined relative to other more important priorities. Graduate students' time was limited by their more pressing responsibilities of classes, teaching or research assistantships or other outside jobs, and their own research. Similarly, faculty members had little time available because they saw their highest priorities as teaching university students, conducting their own research, and acquiring funding.

Scientists in our study preferred to have flexible and limited time commitments in their outreach obligations. A Northwestern University project (CO-VIS) also found that scientists needed flexibility in scheduling outreach. When adequate structure was created for their email and computer-based mentoring program, hundreds of scientists were recruited to participate (O'Neil and Gomez, 1996). Likewise, a chemistry department outreach project at the University of California, Irvine, increased the number of volunteer graduate students by more than an order of magnitude after reorganizing the program to include coordinators to do all administrative and prep work, so that volunteers only had to give 3-4 hours/quarter. This change was based on response to student concerns that the program would take time away from research, teaching, and coursework responsibilities (Waldman et al., 1996). Scientists are concerned with taking too much time away from research obligations (Alper, 1994; Wier, 1991), especially if their efforts are spent coordinating outreach efforts rather than sharing their expertise. Osguthorpe and Patterson (1998)

suggest, based on years of experience with building school-university partnerships, that much more time and effort needs to be spent on the day-to-day practicalities of organizing and running a program. As Milliman (1996) points out, "Unless educational outreach is approached in a businesslike manner, it runs the risk of becoming an almost endless time sink for faculty and staff…"

The second major impediment our study found was the scientists' need for specific information about potential outreach activities, of the type that outreach coordinators could provide. Information about outreach opportunities often did not clearly define the commitment required. Scientists were less likely to do outreach if they had to seek out opportunities or information to clarify the expected commitment. This finding has been corroborated by other studies on outreach and service learning (Abes et al., 2002; Holland, 1999; Wier, 1993). Similarly, one of the major themes learned from a survey of University of Michigan outreach programs, was the importance of organization, which included paid support staff (i.e., outreach coordinators), defined outreach goals, and communication among all participants (LaSavoge et al., 1998).

The third greatest barrier for the scientists in our study was the inadequate value placed on outreach efforts by their advisors, colleagues, and departments. Both graduate students and faculty members believed the other group did not value outreach, as they never explicitly discussed the topic of outreach, even though both were actively involved in outreach. Furthermore, faculty members agreed that outreach could be a beneficial experience for graduate students interested in teaching and academia, as long as it did not interfere with the students' progress toward their degrees.

Graduate students and faculty also perceived that their science departments placed greater value on research. Faculty members reported that their involvement in outreach did not benefit them with regard to tenure or pay, which is well-documented as problematic (Church et al., 2003; Amey et al., 2002; Campus Compact, 2002; Wise et al., 2002; Coor, 1999; Holland, 1999; Keener, 1999; McGrath, 1999; Ray, 1999; Votruba, 1996; Alper, 1994; Hammond, 1994; McCallum, 1994; Diffily, 1989). However, as both our study and other research has found, tenured faculty are much less concerned about these negative perceptions than those without tenure (Abes et al., 2002). Today, only 39% of Campus Compacts' member institutions recognize faculty with service awards, and only 27% consider service learning in tenure and promotion (Campus Compact, 2003), although this is a significant increase compared to recent years. It is common that "those individuals who participated in activities for off-campus publics often found that such activities were not valued by their colleagues at promotion and tenure time. Such work was considered 'overload' for which one should rightfully be rewarded with 'overload pay' instead of career advancement" (Keener, 1999:30). It is not surprising that faculty involved in outreach also find themselves denied merit raises and viewed as "frittering away time" (Alper, 1994). While educational leaders argue that outreach is scholarly work that is interrelated with research and teaching (Church et al., 2003; Rice, 2003; Boyer, 1996; Fear and Sandmann, 1995; McCallum, 1994), faculty members have difficulty understanding how "outreach as scholarship" applies to their academic work (Church et al., 2003). Faculty reward structures have not yet changed to match the goal of greater engagement and the cultural norm of perceiving outreach as non-scholarly, overload work continues to affect the recruitment of faculty into outreach activities (Amey et al., 2002). However, if funding agencies required faculty to conduct outreach, participants in our study viewed their involvement in outreach as appropriate.

Post-Outreach Perspectives

Almost all of the scientists in our study valued their outreach experience. Similarly, Herwitz and Guerra (1996:30) found that university science students were pleasantly surprised at how much they gained from their experience, including becoming more engaged in the subject matter and valuing their role in interacting with young students. In another study, over half of the scientists who had partnered with teachers were also surprised at the program's success (Wier, 1991). Only a few of our scientists viewed their outreach experience negatively, due to logistical, organizational or classroom management problems, or a lack of outreach skills. Other studies have also found that some faculty members lack confidence with, or knowledge of, the skills and techniques of outreach and service (Abes et al., 2002; Campus Compact, 2002; Holland, 1999). It is argued that outreach coordinators can help provide scientists with information about what to expect in the classroom (see for example, Eckelmeyer, 1994; Kirwan, 1994).

CONCLUSIONS

Our study examined scientists' involvement in outreach to K-12 schools and the general public and the factors that motivate or deter their participation. Our findings will be of particular value to researchers who seek to more effectively meet the new "broader impact" requirements of public funding agencies. Our results will also be useful to outreach coordinators, educators, and funding agencies and will benefit the national effort to create the "engaged institution." We have also made several contributions to the literature by examining graduate students', researcher scientists', and faculty members' involvement in K-12 and public outreach.

Looking to the future, scientists' participation in outreach could be increased by considering the factors that motivate or impede their involvement. At a most basic level, outreach activities could be designed to transcend scientists' time constraints due to conflicting priorities. As science outreach programs at the University of California at Irvine (Waldman et al., 1996) and Northwestern University (O'Neil and Gomez, 1996) have learned, many more scientists volunteered once their outreach efforts could be focused on science while other people managed the administrative aspects of outreach. Activities could be identified and organized by a central outreach coordinator who would could clearly define and announce the opportunities, including program goals, activities, time commitment required, skills needed, and other specific information. Outreach activities could be designed that require a limited time commitment of 2-5 hours per month per scientist. Potential participants could be provided with a list of personal and professional benefits they may gain from participating in the outreach activity, such as meeting "broader impact" goals of funding agencies, improving their own teaching and communication skills, and motivating students' interest in science. Whenever possible, the outreach coordinator could personally invite faculty and students to participate in appropriate outreach activities and provide a brief training on their responsibilities. Because word of mouth is such a large factor in scientist recruitment, maintaining contact with participating scientists may provide outreach programs with a source to tap for other scientists.

Beyond these changes that would directly improve the experience for participating scientists, systemic changes toward the "engaged institution" would be required. Institutions would have to embrace the third mission of universities: "service." Efforts toward this would include creating and supporting the outreach coordinator role and including the topic in regular departmental forums for planning. Institutions would need to grapple with the complex topic of recognition and rewards for the involvement of both their staff and students in outreach. Coupled with this, they would have to tackle the difficult topic of managing workload so that outreach is not

overload work, but is integrated into existing teaching, research, and management responsibilities. These types of broader change would likely encourage additional scientists to participate in outreach.

To validate this type of work, the outcomes of outreach on K-12 students and teachers and other beneficiaries would need to be evaluated systematically. The results could be used to recruit more scientists and to appropriately recognize and reward those already involved as well as help with program planning and refinement (Otterbourg 1990). Furthermore, positive evaluations could enhance the prestige of the program, participants, and supporting institution and lead to a change in how outreach is viewed as well as to increased institutional legitimacy and support (Cleary and Benson 1998).

Future research on scientists' involvement in outreach would benefit from expanding this study to include educational institutions of varying size and mission. Furthermore, other scientists, such as researchers in national labs, research institutes, and private industry form a large, potentially untapped resource about which even less is known. Because scientists are concerned with time constraints and competing priorities that limit their participation in outreach, it would be interesting to compare their expectations about the outreach time commitment with their actual experiences. Scientists are also concerned with making a contribution to society, so it would be valuable to learn if their efforts are well spent and have a positive effect on student learning (Abes et al., 2002; Holland, 1999; Osguthorpe and Patterson, 1998; Kaiser, 1996; Hammond, 1994; Wier, 1991; Otterbourg, 1990). As the "broader impact" and "engaged institution" movements grow, scientists' motivations for participation in outreach will shift to be more externally motivated, including factors such as public or private funding opportunities, incentives or rewards, observation of respected colleagues or institutions, evidence of positive impact on academic prestige, and affect on the public image of the institution (Holland, 1999:38). These different motivating factors will offer important new avenues for study, as will the scientists' experiences with outreach under these new circumstances.

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Graduate Students[1]	Faculty Members
Top motivators: 1. Desire to contribute 2. Improve teaching skills 3. Fun and/or enjoyment	**Top motivators:** 1. Desire to contribute 1. Fun and/or enjoyment (tied)
Less important motivators: 4. Advisor or departmental support 5. Funding 6. Academic credit[2] 7. Experience as a recipient[2]	**Less important motivators:** 2. Service credit 3. Experience as a recipient 4. Improve teaching skills 5. Departmental support 6. Funding
[1] Includes researchers reflecting back upon their graduate experience. [2] Researchers rated "experience as recipient" second to last and "academic credit" as least important.	

Table 1. Motivators for participating in outreach (in order of decreasing importance)

Graduate Students[1]	Faculty Members
Top barriers: 1. Lack of time 2. Lack of information about outreach opportunities 3. Lack of support from advisor or department	**Top barriers:** 1. Lack of time 2. Lack of information about outreach opportunities 3. Lack of value to the department
Less important barriers: 4. Funding 5. Lack of value of outreach[2] 6. Lack of interest[2] 7. Not feeling comfortable during outreach[2]	**Less important barriers:** 4. Lack of interest 5. Lack of support for outreach 6. Not feeling comfortable during outreach 7. Funding
[1] Includes researchers reflecting back upon their graduate experience. [2] For graduate students, the last two items were tied for least important. For researchers reflecting back, "not feeling comfortable" was tied for second to last.	

Table 2. Barriers to participation in outreach (in order of decreasing importance)

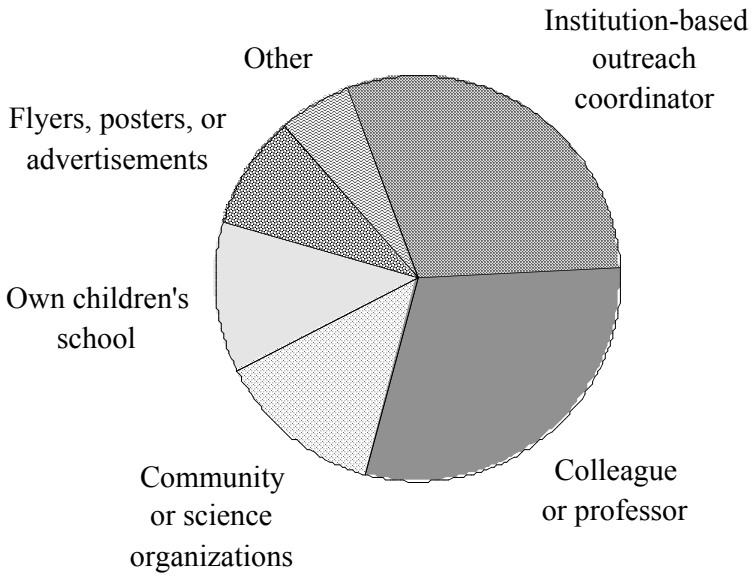

Figure 1. Recruitment Avenues

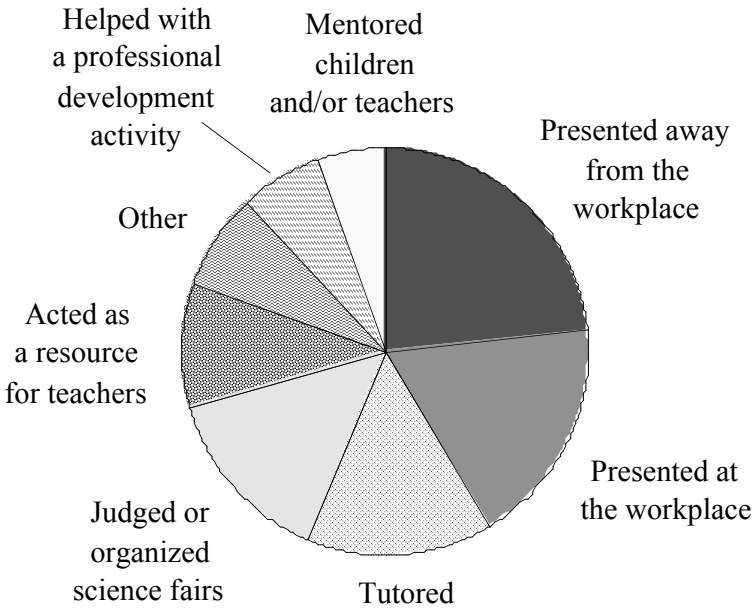

Figure 2: Outreach Activities Undertaken