Chapter 2
Who and What?

Defining the Scope of K-12 Outreach and Engagement

Outreach to whom, where, and how? The answers to these questions are shaped initially by one's interests, experience, and expertise. Once the options are narrowed, the particular individuals, venue, and activities involved will further delineate one's K-12 outreach and engagement efforts.

2.1 Passion

What are you passionate about and what is important for the public to know about it? Do you want to share the excitement of your own research, or offer your perspective on groundbreaking science research recently reported in the news? Perhaps you believe it is important for students to learn about certain science concepts that are largely ignored in pre-college curricula, for example, the value of plants for human existence (Hershey 2002, 2005; Wandersee and Schussler 2001). Or that concepts and processes inherent in evolution underpin all of human understanding about biological phenomena, and yet some people don't even have an opportunity to hear the word in their high school biology classes. Or that genomics is revolutionizing the way scientists and clinicians think about human disease, and yet most U.S. citizens completed their last science class before this word even entered the scientific lexicon.

Perhaps you think it is important for the public to have a more general understand of what science is, for example, that the goal of science research is to discover new knowledge. The vast majority of the country will never have this experience given that most laboratory learning by students involves demonstrations or the completion of step-by-step procedures to yield predictable outcomes (NRC 2006). Indeed, advocates argue that lab learning is an ideal context for developing an understanding of what science is and how it is done, yet involving students doing experiments doesn't mean they develop this understanding (Bell et al. 2003; Hart et al. 2000; Hofstein and Lunetta 2004; Schwartz et al. 2004).

Maybe you would like students develop specific laboratory skills, or just be able to pick up the newspaper and read about a recent study with a critical and informed eye. Neither students nor the general public has regular opportunities to learn about ongoing

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research (Field and Powell 2001). Even when research findings are reported in the mass media, what is said can differ from the original work (Kua et al. 2004). Even more broadly, you may want the public to consider how basic science leads to the development of new knowledge and understanding or how these findings can be useful for solving problems related to health, agriculture, and the environment. Regardless of your interests, it is essential that they serve as a foundation for your outreach. They will help you set the scope of your work, garner funding, recruit and retain participants, collaborators, and other key stakeholders, evaluate the impacts, and spread the word about what you are doing and why it has meaning.

Perhaps your passion isn't immediately obvious, or your work isn't easily translated or otherwise compelling for a pre-college audience. Then, consider what about your work or your profession would be relevant to their lives or important to remember 20 years from now. The scope of science learning includes subject-specific, interdisciplinary, and multidisciplinary concepts and skills, as well as the process, nature, and history of science. Potential topics include:

- Your own research
- Common misconceptions
- Current events, controversies, and topics of public debate
- Subject-specific, interdisciplinary, and multidisciplinary concepts
- Subject-specific, interdisciplinary, and multidisciplinary technologies and skills
- History, processes, and nature of science

In other words, there is *learning science* (conceptual and theoretical knowledge), *learning about science* (knowledge of the nature and processes of science), and *doing science* (expertise in scientific inquiry and problem solving) (Hodson 1998), also described as conceptual understanding, procedural knowledge, and investigative expertise (Hodson 1996). The field is wide open! For an example of how one scientist translating several aspects of his research to engage high school students, see "Evolving Partnership Between a High School Biology Teacher and an Industrial Researcher" in Sect. 2.1.1.

2.1.1 Example of Developing K-12 Outreach and Engagement Activities Based on Current Research

An Evolving Partnership Between a High School Biology Teacher and an Industrial Researcher

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I first became involved in science education as a graduate student at the University of Washington. I participated in a program organized by the Science Education Partnership at Fred Hutchison Cancer Research Center (FHCRC SEP;

http://www.fhcrc.org/education/sep). This program arranged partnerships between scientists (graduate students, post-doctoral fellows, and professors) and high school biology teachers. During the summer, teachers would visit the scientist's lab to learn about research and design a lesson plan. Later in the school year, the scientist would visit the teacher's classroom and assist with the implementation of the new lesson plan, often loaning equipment, providing supplies, etc. Through this program, I first experienced the joy of teaching and the incomparable feeling of success when a student unambiguously demonstrates that he or she understands something new.

After grad school I moved to the San Francisco to work as a researcher at a biotech company called Exelixis. Rather than cloistering myself in industrial research, even further removed from the Real World than the ivory tower of academia, I sought ways to stay involved with science education. Through the Science and Health Education Partnership at the University of California at San Francisco (the program that served as a model for the FHCRC SEP), I connected with David Lauter, a biology teacher at Washington High School in San Francisco. My partnership with David is entering its 5th year and is constantly being modified and improved. I have been fortunate that my Exelixis supervisors have always supported this endeavor by granting me time off to present two or three lessons in David's classroom each year. Exelixis has also supported my efforts by providing reagents and equipment. My overall goal has been to take something from my own research and present it in a way that is useful and informative to the students. This has always been first and foremost an exercise in communication. I have enjoyed the challenge of translating the complexities of my work in a way that will challenge and excite a young audience. David has played an integral part in this process by making sure that my lessons are presented at a level that is appropriate for his students.

The first set of lessons I co-taught in David's classroom derived from the first project I worked on at Exelixis: using genetic analysis of nematode worms to understand how human pharmaceuticals work at the cellular and molecular level. The class exercises began with the analysis of mutant nematodes with various defects in neurophysiology. We then treated the worms with various drugs in order to examine and measure their responses. This led to a discussion about the similarities and differences between worms and humans and how we could ascertain the cellular mechanism of action of the drugs. After a couple years of running these experiments, the focus of my work at Exelixis changed and I was no longer able to supply David with the worms and reagents. However, he felt the experiments were beneficial to his students and wanted to continue doing them, so I helped connect him with another local worm scientist who volunteered to provide the necessary materials.

I, on the other hand, wanted to bring the focus of my new work, stem cell biology, into the high school classroom. This was a challenge because, while worms can easily be grown in a high school lab setting, culturing stem cells typically requires extensive knowledge, technical expertise, and complex equipment. I enlisted the help of another Exelixis colleague and stem cell expert to help me design hands-on activities using only resources available in a high school lab. In addition to these activities, I also wanted to convey something to the students of the controversy surrounding the ethics of stem cell research. I stumbled upon an entire curriculum from the Genetic Science Learning Center at the University of Utah (http://learn.genetics.utah.edu/) that included an excellent lesson plan for a discussion/debate on the ethical use of stem cells in research. The lesson involves a hypothetical scenario where a couple is considering selling the extra embryos generated during their in vitro fertilization procedure to a biotech company. I have facilitated this lesson numerous times and am always impressed by how vociferously the students argue their positions.

After five years of involvement in this partnership with David, I am embarrassed to admit that we have never conducted any formal assessment. However, David continues to invite me back, demonstrating his belief that my work with his students has value. Informal feedback from the students has also been positive. He also attributes the fact that many of his students go on to major in biology in college at least partially to the influence of my lessons. Most importantly to me, the partnership has grown, evolving with my own changing research interests and with the availability of resources, and yet always producing something engaging and enlightening for the students.

2.1.2 Putting Your Passion in Context

Regardless of your passion, it is essential to frame your ideas in the context of the concepts and skills considered important by teachers, schools, districts, and science education policymakers. A good starting point for gaining insight into what is important for students to learn is the local, state, and national science education standards. The national science education standards were published in the mid-1990's with the intent of outlining the essential science concepts and skills students should learn to become scientifically literate citizens (NRC 1996). The standards are organized by discipline and grade level, including what concepts are most appropriately taught together and at what stage of children's development. The American Association for the Advancement of Science (AAAS) spearheaded a complementary effort, titled Project 2061 (http::/www.project2061.org) because of its goal to achieve science literacy nationwide by the year 2061, when Hayley's comet next approaches the earth. Project 2061's *Science for All Americans* (1989) aims to define the knowledge and skills of a scientifically literate individual, and its *Atlas for Science Literacy* (2001) is a large concept map, depicting the connections between concepts, skills, and disciplines and across grade levels.

In early elementary grades, life science standards focus on students' learning about characteristics of organisms, for example, that all organisms have basic needs, including water, air, and an energy source (e.g., food, light, etc.). Students also learn that if these needs aren't met, organisms will not survive. Learning these concepts lays the foundation for understanding the more complex interactions among organisms and their environment that students learn about when they study ecology and evolution. In middle school, these concepts are discussed at the cell, organism, and ecosystem level, while in high school, students consider the molecular underpinnings of a species' success or lack thereof in different habitats.

States, school districts, and even individual schools may have established a more fine-grained set of standards, generally available through state departments of education web site. These standards usually describe what students could and should be learning in different courses at different grades. Additional "scope and sequence" information is often available at the district or state level, describing relationships among scientific ideas as well as what depth of understanding is appropriate at what grade level and what concepts and skills serve as foundations for future learning.

Standards are widely criticized for limiting teachers' instructional choices. Closer examination often reveals that the standards generally make sense and can even be useful for building an argument that particular outreach activities are worthy of class time (see also in Sect. 2.1.3). Standards can be helpful in setting the boundaries of learning appropriate for children of different ages and experience levels, but should not be limiting (Laursen 2006). Rather than dismissing standards outright, use them as guidelines and also consider them seriously in any outreach effort by demonstrating how activities help address standards. Most importantly, consider how to strike a balance between what one is passionate about and what is appropriate for specific classrooms at specific times.

2.1.3 Science Education Standards: An Example of the Slippery Slope

What may seem scientifically acceptable in one set of standards can metamorphose in another set, even if the aim was to clarify by using more concrete verbiage. At state, district, and local levels, additional explanations are articulated in the standards themselves and in the complementary guidelines regarding scope and sequence. The text that is carefully crafted and thoroughly vetted by a multitude of science educators, scientists, and science education policymakers, as in the National Science Education Standards (*NRC 1996*), loses its nuances in translation for classroom practice. Concepts are further muddied by a variety of interpretations available in textbooks and the demand for assessments that yield easy-to-quantify data regarding student knowledge.

For example, the national standards include the following description of biological phenomena related to gene regulation:

> Cell functions are regulated. Regulation occurs both through changes in the activity of the functions performed by proteins and through the selective expression of individual genes. This regulation allows cells to respond to their environment and to control and coordinate cell growth and division…. This differentiation is regulated through the expression of different genes (NRC 1996).

The Virginia standards provide numbered lists under headings focused on the molecular, cellular, and organismal level:

> The student will investigate and understand common mechanisms of inheritance and protein synthesis. Key concepts include cell growth and division, gamete formation, cell

specialization, prediction of inheritance of traits…, genetic variation (mutation, recombination, deletions, additions to DNA),… (*VDE 2001*).

The idea of selective expression of genes, including the role of the environment in this process, is present in the national standards but absent at the state level. Perhaps this is because students are able to develop good understandings of enzymes and their functions at a single molecule level, so choices are made to emphasize the process of gene regulation and expression at the level of specific enzymatic processes. Perhaps the complexities and subtleties of how genes are regulated can quickly become overwhelming, considering the full spectrum of processes involved, from the transduction of external signals like light and heat into cells to the signaling within and between cells to detect, transmit, and respond to those signals.

Yet, students hold onto the misconception that genes determine traits, and that the environment, including one's surroundings and behavioral choices, has little effect in determining the expression of genes. Pointing out the absence of any standard that explicitly addresses the interplay between an organism's genotype, behavior, and environment in determining its traits is not to say that this should be addressed explicitly, but rather as an illustration of how the standards are a starting point, not the boundaries for learning. Rather, scientists can use the standards as a tool for considering the appropriateness of any learning activity with regards to its specific topic of study, as well as its depth and breadth.

2.1.4 Beyond Your Passion

Consider looking beyond your own discipline. Stepping outside of your specialty can encourage you to look at a phenomenon from a learner's perspective, while still allowing for modeling a scientific approach. As a graduate student, I served as a scientist partner in City Science, an NSF-funded Local Systemic Change Initiative project (http://www.nsf.gov/pubs/1997/nsf97145/projects.htm, accessed 11/19/2007) through the Science & Health Education Partnership (SEP) at the University of California at San Francisco (UCSF; http://biochemistry.ucsf.edu/~sep, accessed 11/19/2007) and the San Francisco Unified School District (http://www.sfusd.edu). Through City Science, experienced teachers and volunteer scientists, usually graduate students or post-doctoral fellows, co-taught week-long professional development sessions for beginning elementary teachers using the district's kit-based curricula (e.g., Insights [http://cse.edc.org/curriculum/insightsElem], Full Option Science System [FOSS; http://www.fossweb.com], etc.).

SFUSD's elementary science curricula crossed the disciplines, including instruction not only in life science, but also in physical, earth, and environmental sciences. Because UCSF is a biomedical institution, many of the scientists were teaching outside of their field of expertise and were often learning from the experienced teachers. Although this scenario was most likely the result of geography rather than program goals, it had the very positive outcomes of dispelling teachers' stereotypes about scientists (e.g., that scientists have all of the answers) and of modeling how a scientist approaches a scientific problem that is new to them. All of the curricula being used in the program were inquiry- or problem-based, meaning that they presented scenarios or issues about which students could make observations, propose testable hypotheses, conduct experiments, and develop new understandings. For example, when a scientist faces a new problem, how does one find relevant information, make observations, critique the information and observations, and use it to develop hypotheses, design and conduct experiments, and develop new explanations?

2.1.5 History, Processes, and Nature of Science

Standards not only not only outline content to be learned as it relates to different scientific fields, but also to the history, nature, and processes of science. Although what is meant by the history of science is fairly self-explanatory, discussions about the nature and processes of science are typically the purview of science philosophers and sociologists. The nature of science is defined by what science is and what it is not. For example, science is a human endeavor and scientists are part of a broader scientific community, which has its own values, practices, and mores. The scientific community values "peer review, truthful reporting about the methods and outcomes of investigations, and making public the results of work" (NRC 1996, p. 30). The scientific community is part of a larger society that influences the practices and directions of scientific work. Science is also tentative yet theory-laden. In other words, scientific ideas are based on the development and confirmation of ideas using evidence, and can also be changed or dismissed when new evidence is available. Scientific ideas that have been confirmed time and time again from a number of perspectives and using a variety of tools are less likely to change, and are considered theories.

Learning about the nature of science may seem abstract or so obvious that it seems unnecessary. Yet, proper understanding of science and the scientific enterprise is an essential building block of scientific literacy (Reid and Hodson 1987). Many of the controversies currently under debate across the country are likely because of misunderstandings of what science is and what it is not. It is beyond the scope of this text to describe in any depth the debates regarding embryonic stem cell research or the teaching of evolution alongside creationism or intelligent design in schools. These are just two examples where there appears to be mutually exclusive explanations for the way the world works, one based on faith and the other based on science. Yet, these ways of explaining the world are not mutually exclusive. Rather, faith is based on spirituality and belief and science is based on actual or inferred observations of the natural world. The debate should not be whether faith or science is right, but rather what knowledge is available through faith and what knowledge is available through science.

Similarly, teachers and scientists alike hope that science class is a venue for students to learn about and be engaged in the processes of science. Unfortunately, emphasis on the scientific method often becomes a priority, suggesting that there is one single, universally applicable approach to doing science, and that once one has learned the steps, one will be able to assemble them in order into a coherent whole of doing science. What results are exercises in box checking, where students ask questions, set up experiments that will yield some data, graph those data, and draw some conclusion without careful consideration of the quality of the initial question (e.g., Is there a sound scientific rationale for asking the question? Is the question investigable with the tools available? etc.), whether the investigation is designed to yield data useful for answering the question, whether the data constitute evidence for answering the question, whether graphical or other visual representations of the evidence helps convince the investigators and others of certain conclusions, and what other explanations have already been explored or are hypotheses that serve as the foundation for the design of new investigations.

On the contrary, scientists aim not only to identify and describe causal relationships through their work, but also to identify correlations and solve practical problems (Hodson and Bencze 1998). There is no single algorithm for doing science, and there are few distinct steps (Hodson 1996). Most scientific processes involve developing hypotheses based on existing knowledge and observations, designing investigations to test those hypotheses, collecting and analyzing data, developing explanations based on evidence, developing alternative explanations, and designing investigations or controls to rule out the alternative explanations, but not necessarily in order or in series. Throughout the process, ideas are communicated and developed further, and research questions and methods of data collection and analysis are revised or refined.

In addition, while all science is investigative, not all science is experimental. For example, evolutionary biologists and geologists often don't have the ability to design "experiments" or the luxury to choose controls. Also, some would argue that not all science is hypothesis driven, but instead may be discovery driven or hypothesis generating. For example, there are a number of scientific efforts made possible by the development of high throughput technologies, such as the systematic, community-wide efforts to sequence entire genomes or knock out of all of the genes in an organism's genome. Certainly there is an overarching hypothesis (i.e., if we know the sequence of the genome, then we will gain insights not possible through other means), but most of these efforts are geared to providing data and observations as fodder for generating other hypotheses.

Although scientific content and its history, nature, and processes are discussed separately here, science learning can be enhanced through their integration. For example, by comparing of historical and modern-day scientific ideas, students can learn about how scientific thinking changes with new knowledge and technical capabilities. In addition, learning to make predictions and learning what makes a good prediction is inextricably linked with particular content and theory (Hodson 1996). In other words, it is not possible to make a prediction outside of a particular scientific context, and it is also not possible to evaluate the quality of a prediction without some knowledge about that context. Finally, failure to integrate laboratory learning with the day-to-day concepts and theories students learn about in science class makes it less meaningful and less relevant to learners (NRC 2006).

2.2 People

In addition to considering your passion and where it best fits with the goals of K-12 students and teachers, it is important to keep in mind your interpersonal interests and abilities. In particular, with whom do you want to work, what do they need, and what do they have to offer? Do you enjoy working with young children? Are your own children of school age and would you like to offer their classmates a glimpse into the life of a scientist? Do you want to play a role in preparing students for undergraduate coursework? Do you want to develop insights into the skills, abilities, needs, and interests students have when they enroll in the classes you teach? Do you prefer working with adult learners, for example, teachers who can then impact their students' learning year after year? Is your academic year already filled to the brim such that hosting a teacher or a more mature student for a summer lab internship is a better option than school year activities? Answering these questions is the first step in choosing through which of the myriad ways you might collaborate with K-12 teachers and their students.

2.2.1 Elementary Students and Teachers

There are strong rationales for working with students of all ages, not only to enhance their learning experiences but also to recruit future scientists. For example, when compared to time spent on science, nearly four times as much is spent on reading and language arts and twice as much on mathematics in the early elementary grades, with only a slight evening of the ratio in late elementary grades (Gruber et al. 2002). This may be the result of an emphasis on standardized testing in reading, writing, and mathematics, or teachers' lack of interest in, enthusiasm about, or preparation to teach science, or uncertainty about their science teaching abilities (Manning et al. 1982; Abell and Roth 1991; Stevens and Wenner 1996). Since students' interest in and enthusiasm about science diminishes during the pre-teen years (Simpson and Oliver 1990; Greenfield 1996; Jovanovic and King 1998), efforts to maximize their interest early on may help students maintain a positive attitude during this tumultuous time.

2.2.2 Middle School Students and Teachers

In middle school, equal time is dedicated to each of the subjects, yet teachers are often teaching out of their discipline because of shortages of qualified individuals (Seastrom et al. 2004). Students' interest in science also wanes at this age (Simpson and Oliver 1990; Greenfield 1996; Jovanovic and King 1998). A significant fraction of high school teachers also teach out-of-field, which has a demonstrated impact on student achievement (Darling-Hammond and Hudson 1990; Monk 1994; Goldhaber and Brewer 1997; Ingersoll 1999); only 60% of biology students at the secondary level in 1999–2000 were taught by teachers with a major or minor in biology (Seastrom et al. 2004). Also, eighth graders who expected to have a career in science by age 30 were 1.9 times more likely to complete a baccalaureate degree in life science and 3.4 times more likely to complete a baccalaureate degree in physical science or engineering than those who did not anticipate entering a science career (Tai et al. 2006). This suggests that the middle school years are a prime time for capturing students' interests in a way that still have the potential to affect their pursuit of higher education and, presumably, careers in science.

2.2.3 High School Students and Teachers

At the high school level, laboratory learning experiences, which are correlated with positive attitudes toward science and increased science achievement, are not available to all students (Freedman 1997; NRC 2006). When lab learning is available, often it is not integrated into the flow of instruction and does not include time or opportunities for students to reflect on or discuss their work. In addition, the majority of laboratory activities are demonstrations with predictable outcomes. These activities can play a useful role in illustrating concepts or helping students learn techniques. Yet, if demonstration labs are the only laboratory instruction tools in use, students miss an opportunity to experience the excitement of discovery and learn that science is about generating new knowledge. In addition, only a fraction of high school graduates in the U.S. attend college (45% enroll), and an even smaller fraction major in the sciences (17.6% of bachelor's degrees in the U.S. are conferred in the sciences; National Center for Education Statistics 2005). In fact, the last science class most U.S. citizens take is high school biology (Roey et al. 2001).

2.2.4 Other Points to Consider

Consider also the logistical constraints of the classroom. Some elementary classes and schools have chosen to adopt a schedule that resembles the regimented subject-by-subject timetable of middle and high schools. Others still have more flexible daily plans, allowing for more time to be spent on a particular classroom activity and integration across topics. Some middle and high schools have extended class time for lab work or hands-on activities, while others are structured as a series of 45-min class periods that meet daily.

At a more personal level, consider whether you prefer to work with younger or older students or adults. Some people find that the enthusiasm of young children is contagious, while others find it exhausting. The developmental maturity of students will also stipulate the depth and breadth of topics that make sense to explore. The best way to get a sense of who is most well-aligned with your interests, expertise, and resources is to explore and listen: talk with teachers, talk with parents, or, if you are a parent, consider your own children and their friends and school mates. Indeed, conversations with teachers are often the most fruitful avenue for determining whether a project, lesson, or activity will work with a group of students. Over the years or even year to year at the secondary level, teachers will work with hundreds of students. Their professional experience as well as their sense of students can be invaluable in guiding the design of K-12 O&E efforts.

2.3 Process

Detailed descriptions of how to go about planning and implementing K-12 O&E activities are offered in Chap. 3, while more general factors to consider in advance are offered here. Your interests, time, and resources, as well as those of your K-12 partners, should shape the goals, duration, intensity, and mechanism of your K-12 O&E effort (Fig. 2.1). If you have an interest in working directly with students, you should seek student-focused outreach and engagement opportunities (e.g., mentoring students in science fair projects, leading an after-school science club, etc.; Fig. 2.1). If you are more interested in working with adult learners, seek opportunities to be involved in the professional development of educators. If you have minimal time available during the school day, consider collaborating with teachers to provide curriculum enhancements like experimental materials and kit-based lessons. Finally, if you would like to collaborate with a teacher in working with students, develop an ongoing partnership with a teacher.

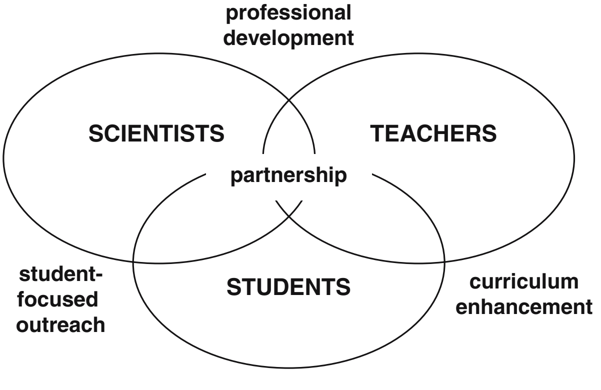

Fig. 2.1 Mechanisms of K-12 Outreach and Engagement. The involvement of different individuals will guide the type of activity that is possible. For example, kit-based lessons can be co-developed with teachers and either taught by the teacher alone (i.e., curriculum enhancement) or co-taught by the teacher and scientist (i.e., partnership). If the effort only involves scientists and teachers, it is considered professional development

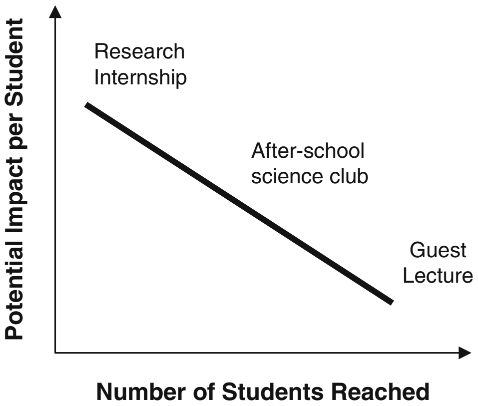

Fig. 2.2 Hypothetical relationship between the number of students reached and impact per student. Some K-12 O&E activities will reach larger numbers of students, but are less likely to have a long-term effect on students' interest or engagement in science. For example, guest lectures can enhance students' attention during that particular class session but are less likely to influence their choices to pursue a bachelor's degree or career in science. More intensive one-on-one experiences, like research internships, are predicted to be more effective at encouraging students to pursue further education and careers in science

Goal setting is the next step. Although it may seem odd to generate goals after you decide what kind of work is of interest given the time and resources available, keeping these factors in mind from the outset will help ensure that the goals that are established are realistic. Consider and prioritize short, medium, and long-range goals, including changes in (1) knowledge and skills, (2) behavior and attitudes, and (3) status and level of functioning. Changes in knowledge or skills can happen on relatively short timescales, for example, during the course of a lesson or unit. If such activities are repeated several times, many students can be involved. Changes in status, for example, a student's choice to pursue a career in science, will require interactions of longer duration and greater intensity, and thus are less scaleable (Figs. 2.2 and 2.3).

Other factors to consider are the role you would like to play and the scope of your work. For example, do you consider yourself an advocate, a resource, or a partner (Bybee and Morrow 1998)? In other words, do you see yourself speaking out about the value of pre-college science education at meetings of Parent–Teacher Associations or scientific societies? Or developing a longstanding relationship with a local teacher? Do you see yourself working with one or a few students who you hope with pursue careers in science? Or with one or a few teachers who will then reach an exponential number of students? In essence, the choice becomes whether your priority is to interact with many people for a short time or a few people over an extended time, and whether those people are students with whom you will interact directly or teachers who will interact with hundreds or thousands of students over the years to come.

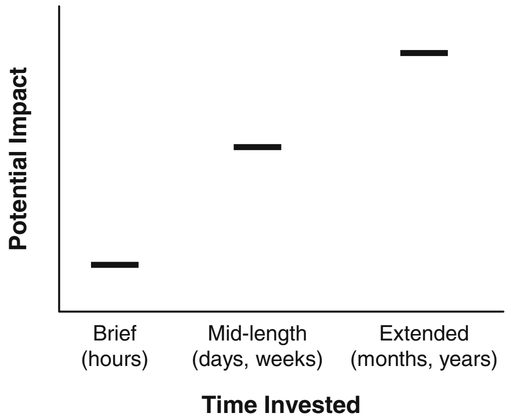

Fig. 2.3 Hypothetical relationship between time invested and the potential for impact. No causal relationship has been identified between time invested by students, teachers, or scientists in K-12 O&E activities and the impact on those involved, most likely because the logistics of such a study are prohibitive. Such a relationship is hypothesized because there is such a relationship between the duration of teacher professional development and impact on classroom teaching practices (e.g., Garet et al. 2001; Shields et al. 1998; Weiss et al. 1998)

There is no single audience, no single curriculum, no single approach, and no single venue that is "right." Rather, regardless of the people, topics, duration, or intensity of K-12 outreach and engagement activities, the following questions can guide your efforts:

- Who are the key stakeholders and what are ways to ensure they are bought in?
- What do you, your collaborators, and key stakeholders hope to achieve?
- What are ways to ensure that activities, materials, and supplies safe and age-appropriate with respect to students' intellect, interests, and manual dexterity?
- What are ways to ensure the activities are included at a thoughtful place in the curriculum and integrated into the flow of instruction?
- What are ways to ensure that the students see that the activities are worthwhile rather than just busy work, fun stuff to do, or a "day off" of school?
- In what ways will you, your collaborators, and other stakeholders know you have mage progress toward achieving your goals?

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