The Power of Partnerships

A GUIDE FROM THE NSF GRADUATE STEM FELLOWS IN K-12 EDUCATION (GK-12) PROGRAM

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Editorial Staff:
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OUR NATION REQUIRES a strong science, technology, engineering, and mathematics (STEM) workforce to deliver the innovations that are so critical for economic competitiveness. A healthy STEM education system—from kindergarten through graduate training—is required to meet these workforce needs. While many people refer to the STEM education system as a linear pipeline, the National Science Foundation Graduate STEM Fellows In K-12 Education Program (GK-12) bends that pipeline to create a full circle of engagement from kindergarteners through graduate students. By connecting the graduate researchers directly with K-12 teachers and students, the NSF GK-12 Program provides hands-on, inquiry-based STEM content to classrooms in the U.S. and Puerto Rico.

This “full circle” GK-12 approach provides benefits for K-12 students, teachers, and the Fellows themselves. GK-12 Fellows bring a love of discovery and inquiry into the classroom as well as up-to-date STEM content to K-12 teachers. They provide role models for younger students to pursue careers in science and engineering. The impact on students to “know” a scientist who is both accessible and enthusiastic about the discovery of science cannot be understated, not to mention the students’ increased science comprehension as a result of the enriched GK-12 experience. In return, the Fellows hone their communication skills and learn pedagogy from experienced K-12 teachers. The GK-12 Fellows comprise a cadre of scientists capable of returning to K-12 classrooms as science teachers themselves, or as better teaching assistants and professors in the university setting. In an age where scientists must learn broad skills to succeed, the abilities that graduate students acquire through the GK-12 experience are critical for their success in a variety of careers. GK-12 Fellows are part of a new generation of renaissance scientists and engineers who can do much more than research—they give back to society through their teaching, public engagement, and rich communication skills. What better way to populate needed science teaching positions than with scientists trained in pedagogy and communication?

GK-12 has provided a model of STEM teaching based on curiosity-driven lesson plans, and hands-on experience in science and engineering for students and teachers that connects every stage of the STEM pipeline. The GK-12 approach of partnerships between universities and K-12 schools provides an exciting way

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to meet the Next Generation Science Standards—learning the process of science directly from scientists and engineers. At the same time, the GK-12 approach fulfills the NSF’s broader impacts criteria by creating meaningful engagement between researchers and the community. Such a model should be emulated across the country to ensure that the next generation of scientists and engineers develop a love for discovery and are ready to contribute to our nation’s strong STEM-based innovation system. Beyond our shores, the GK-12 approach offers great value in connecting K-12 students with young scientists and engineers, and is under consideration for adoption in several countries around the world.

We encourage the adoption and wide expansion of the GK-12 approach to foster strong partnerships and complete the STEM “circle” so critical to ensuring the well-being of the STEM enterprise and America’s innovation ecosystem. We hope that faculty, graduate students, and K-12 teachers will use this publication as a beacon for creating their own university K-12 school partnerships to transform lives and strengthen communities.

Bruce Alberts
Editor-in-Chief, Science
Professor Emeritus,
University of California,
San Francisco

Rita Colwell
Distinguished University Professor,
University of Maryland, College Park, and
Johns Hopkins University Bloomberg School
of Public Health

2 http://www.nextgenscience.org/next-generation-science-standards
To bring you the multiple experiences, lessons learned, practices and activities developed through the 12 years of the life of the Graduate STEM Fellows in K-12 Education (GK–12) Program would be an impossible task. Nevertheless, there is much to be shared. This guide emerged as a result of initial conversations between the National Science Foundation (NSF) GK-12 program team and the American Association for the Advancement of Science (AAAS) to determine how best to capture the legacy of GK-12. A call went out to the GK-12 community to take on this challenge. Thirty four participants from the GK-12 program were invited to Washington, D.C. to brainstorm just how best to convey the richness of the program to others. This team represented Principal Investigators, Teachers, Evaluators, Program Coordinators and Fellows who worked tirelessly discussing, assembling, organizing and reviewing multiple iterations of the manuscript to produce this final product. While preparing this guide it became clear to all that there is no single GK-12 model but multiple models. This has been the beauty of the GK-12 program. It also became clear to all that GK-12 was a program of Powers:

First of all, there is the essential Power of Partnerships between institutions of higher education and K-12 schools, as well as partnerships between Fellows and Teachers. These were true and successful partnerships that brought multiple benefits to all. The Power of Partnership was also exemplified in the longstanding collaboration between the GK-12 program staff and AAAS staff and the multiple activities and products that resulted from this collaboration including the production of this guide. Of course, no partnership is possible without the spirit and energy of its people.

Second, there is the Power of Discovery, discovery experienced by Fellows through their scientific research, discovery experienced by Teachers while working with Fellows in bringing their research to the classrooms, and discovery experienced through the “Aha” moments of children when they understood a new scientific concept or when they were marveled by the wonders of science.

Third, GK-12 brought the Power of Teaching and Learning through inquiry to hundreds of classrooms in rural and urban areas, to small schools and large ones in the U.S., and to some far corners of the world. It is the Power of Teaching and Learning that will produce generations of life-long learners.

And finally, GK-12 is about the Power of Community, a community bonded by common goals and the love and commitment of making a difference. I have been proud and privileged to have served the GK-12 community for these many years and believe that the legacy of the program will live on. It is my hope that this guide will inspire others to try the GK-12 approach so that they will experience and harness the Powers that this program has brought to others.

Sonia Ortega
Program Director
National Science Foundation
This guide marks a number of “firsts” and “lasts.” For most of the life of GK-12 as a program and a community, AAAS has collaborated with NSF to create opportunities for learning, achievement, and celebration.

Together, AAAS and NSF have honored Fellows, their mentors, peer teachers, students, and evaluators. We have fostered exchanges, partnerships, and the development of skills that scientists today and tomorrow will apply. With a website (http://www.gk12.org/) that continues, AAAS will feed multi-media communications to various publics, reminding all that science literacy and numeracy are tools for the ages.

For all these firsts, AAAS is grateful to the principal investigators and teams supported by the NSF Program on Graduate STEM Fellows in K-12 Education (GK–12). They are the expertise and energy that gave more than a “taste of science” to scores of children across the United States (and in a few cases, beyond our borders).

To these accomplishments, a “seeding of the next generation,” we now add a final first—a guide to assist those who wish to try their hand at instituting innovative teaching and learning that stretches from graduate training to the precollege classroom. To do all this as part of a single program is stunning. To do it for more than a decade is a testament to hundreds of participants, now emissaries, displaying the power of partnership and federal investments in local education practice. To codify it in the pages that follow is to offer “extra credit.”

To Sonia Ortega and her dedicated revolving band of program directors, we are forever grateful. This includes our privilege in working with additions to the “regular” NSF staff, exemplary K-12 teachers known as Albert Einstein Fellows, who were assigned to the GK-12 program, bringing their insights and practical experience to the effort. We could not hope for better colleagues in every sense of the word “collegiality.”

As for the “lasts,” we fondly recall conferences that brought fellowship through both affinity and dissimilarity. Alas, there will be no more under the GK-12 banner. Our annual months-long preparation for the conference was the annual renewal of this community and an ongoing re-shaping of the “GK-12 model.” As this volume attests, the model is more accurately a collection of experiments borne of university settings, extended into elementary, middle, and high schools, then connected with real communities, their leaders, parents, and supporters.

All recognized the power of science education to enrich, inform, and transform. That now must continue with a myriad of patrons, venues, and designs. We welcome those manifestations. It is what GK-12 spawned. It is the program’s legacy. It is what we, and those who gamely follow, shall continue to celebrate.

Our gratitude abounds to NSF for making this so much more than a gleam in the eye. AAAS was privileged to facilitate the life of a program needed then and still needed now.

For the work of science educators is never done. This guide, the product of experiences gone right (and wrong), is a beacon to the future. We urge readers to behold it, but moreover, use it, embellish it, and record in the margins your deeds alongside ours.

Daryl Chubin
Senior Advisor
AAAS Education and Human Resources

Betty Calinger
Project Director
AAAS Education and Human Resources
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INTRODUCTION

THIS GUIDE PROVIDES EFFECTIVE PRACTICES for anyone—university faculty member, K–12 teacher, or administrator—who wants to create a project that partners science, technology, engineering, and mathematics (STEM) graduate students (Fellows) with K–12 teachers on a sustained basis. These recommendations come from the community of faculty members, graduate students, K–12 teachers, program managers, and evaluators who participated in the U.S. National Science Foundation (NSF) Graduate STEM Fellows in K–12 Education (GK–12) Program from its start in 1999 through 2012. The guide was written to capture the knowledge and experiences of the GK–12 alumni community, which now includes more than 10,000 graduate students, 1,000 principal investigators (university faculty), 300 project evaluators, and 12,000 K–12 teachers. It is our hope that the GK–12 approach will be implemented broadly and that this guide will provide clear details for how to create a successful GK–12 type of project anywhere. Starting a GK–12 project is a serious undertaking, but it is one that provides tremendous professional and personal rewards for all participants. For many, it has been a seminal career experience.

ESTABLISHING A COMMON LANGUAGE

Throughout this guide, the different aspects of a GK–12 project will be discussed, from design through implementation and sustainability. Although the term “GK–12” has historically been defined specifically as the program that was sponsored by the NSF, this guide will use GK–12 Project to refer to any project that is modeled on this foundation.

All projects described in the pages that follow involve graduate students from STEM fields; these students are called GK–12 Fellows. The K–12 teachers who are involved in the projects will be referred to as GK–12 Teachers when they have a leadership or coordinating role. Unless otherwise noted, the term student will refer to a K–12 student. The term project director will be used to denote the lead university person in the project; this is usually, but not always, the principal investigator, or PI, of the grant.
WHY SHOULD ONE INVEST IN A GK–12 PROJECT?
The GK–12 community is a passionate one because it has experienced the transformative power of the GK–12 approach to K–12 and STEM graduate education; the GK–12 approach brings research and inquiry education to the K–12 classroom via a sustained partnership between scientists (STEM graduate students) and K–12 teachers. Quantifiable benefits, summarized in Chapter 12, have been reported in the peer-reviewed literature (e.g., Beghetto 2009, McBride et al. 2011, Raju and Clayson 2011, Stamp and O’Brien 2005, Trautmann and Krasny 2006) and in an evaluation of the GK–12 program by the consulting firm Abt Associates (2010). They include the improvement of K–12 students’ and teachers’ science literacy, enhancement of GK–12 Fellows’ communication and research skills, and promotion of K–12 students’ and teachers’ understanding of the process of science. In addition, GK–12 Fellows are positive role models: K–12 students have developed relationships with the Fellows, and some K–12 students have been inspired to pursue a STEM career. Equally valuable, the Fellows have come to embrace the importance of being role models: They understand why their professions depend on it and have come to welcome the importance of that role in their own professional lives. Individual GK–12 projects have documented benefits for their Fellows, for K–12 students, and for teachers; many of these benefits are captured in the book The NSF GK–12 Program: A Decade of Innovation in Graduate STEM Training and K–12 Learning (AAAS 2011). Communicating directly with GK–12 alumni, including Fellows, Teachers, PIs, and evaluators (see http://www.gk12.org/alumni-center for names and contact information) is another way to learn about the program’s value.

OVERVIEW
Figure 0.1 illustrates the main steps in designing, implementing, evaluating, and sustaining a GK–12 project. The remainder of this introduction will discuss the basics of getting started, with some questions highlighted that you should ask as you initiate your planning. The rest of the guide will take you through the other steps in this figure.

First Steps
Before launching a project based on the GK–12 approach, we recommend (1) being able to clearly articulate how and why GK–12 projects have been successful (see Chapter 12), and (2) determining how the GK–12 model selected can have value in your particular setting.

How can one determine whether a GK–12 project will have value for the local university, K–12 teachers, and students? Optimally, a formal and comprehensive needs assessment will answer this question. However, there are effective ways to evaluate the need and potential value of the project without completing a formal needs assessment. Most importantly, does the university already have a program that partners STEM graduate students with teachers in K–12 classrooms on a sustained basis? If not, then this kind of project likely will provide value. There are some key ingredients of successful GK–12 projects. If some of these elements already exist, then it will be easier to set up a project; however, if these elements do not yet exist, then that alone might indicate an even greater need for this kind of project. Some of the issues to consider in your assessment are (i) whether the university has a high-quality professional development program that provides science communication and/or pedagogical training for STEM graduate students, (2) whether K–12 teachers generally teach STEM subjects with high proficiency, and (3) whether any professional development opportunities are offered through the university for STEM K–12 teachers.
Investigate the university’s STEM outreach efforts: What is their history and performance? Programs may be offered at all levels (department, college, university-wide) and may be funded through STEM education and outreach programs of federal agencies (e.g., NSF, the U.S. Department of Agriculture, and the National Aeronautics and Space Administration). The people who lead these programs can often give insight into developing and running a successful project and forming positive connections with K–12 schools. Teachers and K–12 administrators who have been involved in university science outreach projects can provide equally valuable insights and become future partners, given the opportunity. As with any partnership, the ultimate goal is to ensure all parties that their opinions and experiences are valued and their needs met.

Sharing and vetting ideas with others
We recommend vetting ideas for projects that follow the GK–12 approach with people who have experience with this type of project before developing a full plan or proposal. Vetting is especially important with STEM research scientists, who often have little experience with K–12 outreach. Members of the GK–12 alumni community, directors of museum outreach and community outreach programs, and school district staff or teachers responsible for the district-wide science and mathematics curriculum can all provide good feedback. Many are enthusiastic supporters of new projects that follow the GK–12 approach and will readily provide advice and perspective if contacted; a list of GK–12 projects and their websites is available at http://www.gk12.org.

Sustainability
Keep project sustainability in mind as you develop your ideas. A successful project depends upon institutional commitment that goes beyond a small number of people who develop and lead the effort. Because the project is a partnership most commonly between a university and a school or school district, it is essential that university and K–12 administrators make institutional commitments to an agreed-upon time frame for the project. If you decide to begin a GK–12 project, you should consider whether you and the possible partner institutions are committed to the project’s sustainability if it proves successful. A project can’t be sustained if it depends on only a few committed individuals, although a few champions are necessary to get a project started.

Costs
If a university values the GK–12 approach and chooses to start a GK–12 project, it must designate resources (time and money)—potentially supported partially or wholly with external funds—for the project. If faculty or staff workloads are flexible enough, then adjusting them is one way of providing faculty and staff time for instruction and coordination. Always, however, there is some time and monetary cost to running a GK–12 type of project. Major costs are time and, perhaps, compensation for a coordinator and the participating STEM graduate students.

Compensation mechanisms for the GK–12 Fellows—financial support and/or academic credit of some kind, perhaps for a certificate—will be necessary to ensure that the STEM graduate students engage in a K–12 partnership that lasts long enough to be useful. Teaching certificate programs for STEM graduate students are growing in popularity nationally and may offer a cost-effective way to support and sustain a GK–12 project.

“So I want to persuade you [scientists] to spend time in the classroom, talking and showing young people what it is that your work can mean, and what it means to you. I want us all to think about new and creative ways to engage young people in science and engineering...”

—President Barack Obama
April 2009, National Academy of Sciences
GK–12 of the Future
Even as the NSF GK–12 program ends, the GK–12 approach in various forms will continue. The chapters that follow provide detailed guidance on the major elements of the GK–12 projects identified in the preceding text, including case studies, pitfalls, and solutions. The chapters describe highly effective practices developed by the national GK–12 community over a decade. It is our hope that those who set out to create their own GK–12 project will find this publication a useful guide.

FOR MORE INFORMATION

CHAPTER 1
OVERVIEW OF THE GK–12 APPROACH

Ana-Rita Mayol, Larry Johnson, and Donna Llewellyn

MANY GK–12 PROJECTS HAVE BEEN SUCCESSFULLY IMPLEMENTED ACROSS THE NATION. These projects were designed to improve STEM graduate students’ pedagogical and communication skills, and to provide Teachers with new pedagogical techniques and STEM content and to increase STEM knowledge in K–12 students. GK–12 projects range from being discipline specific to multidisciplinary, and there are many potential models within the overarching GK–12 structure. This chapter provides an overview of the infrastructure needed and the different models used. GK–12 projects integrate administrative, academic, research, and educational activities in partnerships among universities, K–12 institutions, and informal science projects.

GK–12 MODELS
GK–12 projects have historically been organized according to many different models. The model selected should be aligned with the project’s goals and objectives, discipline, and context. What follows is a brief description of some of the more popular models that have been used in successful GK–12 projects. Note that these models are not mutually exclusive, as GK–12 projects can utilize different aspects of them. Note also that these are not the only existing models; rather, they are given as a starting point for a project.

The Fellow–Teacher Partnership. The most common model assigns a GK–12 Fellow to a specific partner GK–12 Teacher or, in some cases, to a small team of Teachers. Together, they develop and implement lesson plans with varied pedagogical styles. Most projects encourage their Fellow–Teacher teams to use engaging instructional strategies in the classroom, such as hands-on activities, active learning, and inquiry-based or problem-based learning scenarios. GK–12 projects provide training in specific pedagogical skills for Fellows, Teachers, or both groups. The Fellow–Teacher teams implement lessons and/or labs together in the classroom. This model includes summer or semester-long intensive training in pedagogical skills that varies with the emphasis of the project, followed by regularly scheduled meetings (such as weekly and monthly meetings).

The Resident Scientist. As a variant on the preceding model, some GK–12 projects adopt the model of having resident scientists in a school or school district. In this model, the Fellows prepare lessons prior to being introduced to the classroom. Then, once the Fellows are incorporated into the school, the Teacher and/or Fellows offer the lessons to the students and/or Teachers. Again, this
model includes a summer or semester-long intensive training project.

**Fellows Work Across Multiple Schools or Districts.** Some GK–12 projects train their Fellows to offer a series of lessons in different schools or even different school districts. Fellows are responsible for disseminating the GK–12 lessons in targeted schools. Some of these projects have science kits that contain hands-on activities prepared and shipped to schools for a certain length of time. Since this model often has the disadvantage of not allowing a strong bond to be built up among Fellows, Teachers, and students, the model is most suitable when the schools are at remote locations (relative to where the university is). Training for this model typically includes instruction in pedagogical and communication skills for Fellows and training in the use of science kits for Teachers.

**Traveling Lessons.** Another model that suits remote or scattered locations has the Fellows using a traveling laboratory to visit schools and impart laboratory techniques in STEM fields to K–12 students. Fellows develop a series of laboratory activities under the mentorship of an education expert and typically visit many schools at least once. This model is usually used in one specific discipline and focuses mainly on developing Fellows’ pedagogical skills and motivating K–12 students in STEM disciplines. Training for this model includes instruction in pedagogical and communication skills for Fellows and training in the use of science kits for Teachers.

**Teachers with Multiple Levels of Participation.** Some GK–12 projects recruit Teachers to perform two different functions: Lead Teachers participate in the project for the duration of the academic year, including the summer. Participating Teachers partake of summer training and/or a summer research project. Lead Teachers typically work on a team with an assigned Fellow. Participating Teachers can have classroom visits from GK–12 Fellows during the academic year and take part in small research projects during the semester.

**One- versus Two-year Fellowships.** Most GK–12 projects recruit Fellows for a period of one year, aligned with the school’s academic calendar. Some projects have mixed cohorts of new Fellows and experienced Fellows. These projects use the experienced Fellows to mentor new Fellows and/or as presenters during training sessions and monthly meetings. The advantages of having one-year versus two-year fellowships will depend on your project’s goals and objectives.

### Additional Activities

**Research-based Lessons.** Many Fellows in the GK–12 projects develop and implement hands-on lessons that are aligned with state and district standards and that bring current research findings into the classroom. These Fellows must take into account the courses and/or disciplines into which the lessons will be integrated. This model also includes summer or semester-long intensive training in pedagogical skills, followed by regularly scheduled meetings (such as weekly and monthly meetings).

**Research Experience for Teachers.** This popular model offers research experiences for Teachers during the summer. Such experience helps the Teachers...
familiarize themselves with science content and the techniques of the project and allows them to work with Fellows, preparing research-based lessons correlated with the curriculum.

**Mechanisms and Infrastructure**

Successful GK–12 projects have effective mechanisms and infrastructure to support their various activities. Figure 1.1 illustrates a basic organizational structure of a generic GK–12 project that can be used as a guide during the implementation process.

To build a successful project, you must first establish the goals, outcomes, and expectations of the different members of the GK–12 community. These decisions will then dictate the infrastructure and organizational structure that are needed to support the project. Note that there should be open communication among all members of the community, as well as regular evaluation of the critical areas of the project, so that it can be improved with time. In general terms, the roles and responsibilities of each participant shown in Figure 1.1 are described next.

**Leadership** is essential for decision making, planning, selection of committee members, directing, and evaluation of the project. For agency-funded projects, the leader of the project is the principal investigator (PI), who, along with the co-principal investigators (Co-PIs), designs and leads the project. For the rest of this guide, the primary leader will be referred to as the project director. GK–12 leadership often includes disciplinary STEM faculty members as well as education experts.

An **evaluator** assesses the progress of the project in terms of the goals and objectives. The evaluator works closely with the leadership team to establish the expected outcomes of the project. Often, he or she visits the classroom to assess the progress of the Fellows and Teachers, the Fellow–Teacher partnership, and/or the learning of the students affected by the project. Some projects also include evaluation of their leadership. It is highly recommended that projects be evaluated periodically. Agency-funded projects often require quantitative metrics and an external evaluator.

The **advisory committee** is ideally composed of experts in the discipline(s) of the project as well as related education experts. In some cases, former GK–12 Fellows and Teachers become part of the committee. They are responsible for (1) identifying the relevant discipline-specific topics; (2) giving input to the Fellows and Teachers who are undergoing the training, by providing relevant topics, presenters, and/or activities; (3) selecting and monitoring the progress of the Fellows; (4) providing feedback and attending summer and semester-long training for Fellows and Teachers; and (5) suggesting changes in the project on the basis of the data they have compiled in the performance of their duties.

**QUESTIONS TO ASK WHEN CHOOSING A GK-12 MODEL**

- What are the policies of local schools regarding outside personnel working with teachers and students inside schools?
- Are there science centers or museums that might be appropriate placements for graduate students?
- Can graduate students walk or drive to schools, or must they travel significant distances, perhaps needing overnight accommodations?
- How will the discipline or research focus of participating graduate students relate to the K–12 school or state curriculum?
- What does the lead institution (usually the university) have in the way of resources and personnel to manage a GK–12 project?
- Are there existing partnerships between the university and K–12 schools, science centers, or museums that could be utilized?
The project coordinator is the person who is in charge of the day-to-day implementation of the project. In some projects, this person is the project director; however, that is not always the case. When it is a separate person, it is vital that the project director and project coordinator be in regular communication and agree on the overall vision and goals of the project.

Research mentors are responsible for (1) assisting Fellows in the preparation of educational materials by providing feedback on scientific content and relevance; (2) mentoring Fellows in the development of scientific writing skills; (3) contributing to Fellow–Teacher team training (e.g., by giving a scientific talk, being a role model, visiting schools); (4) attending key meetings of the Fellow–Teacher team training project; and (5) monitoring the progress of the Fellow to maintain a balance of GK–12 and graduate research activities. Often, these mentors are the graduate research advisors of (some of) the Fellows.

School district and school administration responsibilities include (1) supporting Teachers in the implementation of the project; (2) examining the impact of the partnership; (3) communicating with project leaders about the progress and outcomes of the partnership; and (4) assisting in creating and implementing effective strategies for sustaining the project.

The administrative staff supports all participants in the project by assisting in the coordination of activities and training and by providing administrative and clerical support.

Fellows’ responsibilities may include (1) maintaining progress in their academic and research activities; (2) devoting an established number of hours per week on educational activities (e.g., developing lessons and/or labs and offering workshops, laboratory visits, field trips, and Teacher training, depending on the model of the project); (3) preparing educational lessons related to their research and/or the discipline of the project; (4) attending summer and academic-year training projects and meetings; (5) working on a team with one or more Teachers at one or more assigned schools (depending on the model); and (6) submitting reports and any other documentation required by the project.

Teachers’ responsibilities may include (1) working with one or more assigned Fellows in the development and implementation of lessons (depending on the model); (2) attending summer and semester-long training activities and meetings; (3) submitting reports and any other documentation required by the project; and (4) completing a laboratory or field experience at a Fellow’s laboratory (desirable, but not usually required).

In addition, some projects include an educational expert, who is an experienced professional in education or a retired teacher. This person monitors the progress of Fellows and Teachers in the implementation of lessons and meets with Fellows regularly, including visiting classrooms and providing feedback on educational activities.

Different GK–12 models might require different responsibilities. It is important that the leadership, in collaboration with the advisory committee, clearly establish the specific roles of their Fellows and Teachers, and provide training and mentoring for them to be successful.

Timeline
The GK–12 project is most effective when the Fellows and Teacher are recruited for either a 12-month or 24-month period, depending on the model, discipline, and/or funds available. The ideal timeline for implementing a successful project is to align it with the school year, providing for training, the preparation of lessons plans, and the introduction of Teachers into Fellows’ research during the summer prior to the Teachers’ school year participation. Fellows are then incorporated into the schools during the academic year.

“The most meaningful, formative, and fulfilling year of my life to date.”
—GK–12 Fellow, STEP project at Georgia Tech
EXEMPLARS

GRADUATE STUDENTS PARTNER WITH TEACHERS IN K–12 SCHOOLS

University of Iowa—Symbi Program
http://www.gk12.iastate.edu/default.asp
In the most common version of the GK–12 model, a graduate student is partnered with a single teacher for 10–15 hours per week for the entire school year. The University of Iowa’s Symbi GK–12 Project is typical. Each Fellow works with a selected middle school or high school science teacher to leverage the Fellow’s research experiences as the two develop innovative and engaging science activities for the students. The Fellows spend one full day every week in a science classroom throughout the public school year, performing the duties of a “resident scientist/engineer” as they interact with their partnering teacher and students.

GRADUATE STUDENTS PARTNER WITH SCIENCE CENTERS

Boise State University—Utilizing Local Resources and Educational Settings to Stimulate K–12 Learning
http://gk12.boisestate.edu/
Boise State’s GK–12 project focuses on using local and regional science issues to stimulate learning in the K–12 community. GK–12 Fellows from the Departments of Biology and Geosciences partner with three local learning centers—the MK Nature Center, the Foothills Learning Center, and the Boise WaterShed Environmental Education Center—to develop and deliver educational activities. K–12 classes visit the learning centers to use some of the activities developed, while traditional classroom settings use other activities through outreach.

GRADUATE STUDENTS PARTNER WITH REMOTE SCHOOLS

University of Wyoming—Science Posse
http://www.uwyo.edu/scienceposse
Some states, such as Wyoming, have a low population density, with schools separated by many miles. The University of Wyoming’s Science Posse GK–12 project provides opportunities for K–12 teachers and students to visit the labs at the university, or a teacher can request a visit from a Fellow to his or her classroom, either in person or through the Virtual Science Posse. The project offers a menu of presentations, labs, and activities that teachers can select from, and the project coordinator matches the request to the appropriate Fellow and schedules the visit. In some cases, Fellows travel to distant schools hundreds of miles away and may stay overnight working with teachers and students in the same school for several days.
CHAPTER 2
CREATING INSTITUTIONAL PARTNERSHIPS

PARTNERSHIPS ARE COOPERATIVE VENTURES between two or more groups or individuals. Partners establish common goals and objectives and jointly determine methods for achieving those goals. However, each partner needs to recognize that mutual goals and benefits can be achieved only by working well together. Although one partner may initiate the relationship, have fiduciary control, or be the instigator of the joint project, all partners must have a voice in the implementation and evaluation process, or the partnership will break down and become an unequal dominant–submissive relationship. This kind of relationship often leads to a lack of cooperation and disagreement in the achievement of goals for the project. Thus, the careful development of partnerships is essential to the success of the GK–12 approach.

INITIATING PARTNERSHIPS

In GK–12 projects, partnerships are generally established between a university and K–12 schools (school districts, principals, and teachers). Other types of partnerships may be involved, such as a partnership between a university and a nature center, science center, community group, etc., but this chapter focuses on university–K–12 partnerships. Also, since, in the GK–12 approach, the university usually initiates collaborations, the chapter assumes that the university will reach out to establish partnerships with the K–12 community. Chapter 5 elaborates on the “care and feeding” of these partnerships, and Chapter 7 gives examples of extending partnerships beyond this standard setting.¹

The current chapter also discusses how to initiate university–school partnerships and provides guidelines as to what has proven successful. This discussion is followed with practical suggestions for how to best approach schools to form a partnership, as well as suggestions for how to utilize already established university connections to K–12 schools. Finally, we examine effective practices to apply when establishing partnerships aimed at various school or community demographics, at different types of institution (e.g., public vs. private), and at different geographic locations (e.g., rural vs. urban).

FIRST STEPS

In establishing a partnership between a university and the K–12 community, consider a few key issues. It is a good idea to establish a single conduit for ¹ However, one case study provides an example of the reverse, a school approaching the university.

The Washington State University-Vancouver GK-12 project partnered with local schools to restore a pond.

CHAPTER HIGHLIGHTS

▷ Have the university select a single liaison for communicating with schools to establish partnerships.
▷ Approach partnerships from two directions. Working from the top down to establish partnerships with school districts can be beneficial, but so is going directly to teachers at the grassroots level to recruit enthusiastic participants.
▷ Use established university-school networks. Also, use existing school projects to develop contacts and partnerships and to find teachers who are eager to partner.
▷ Learn about the demographics of the communities in which you hope to establish partnership.
▷ Cultivate partnerships by making sure that everyone understands and appreciates the benefits for all.
communication, to make it clear to schools who the university liaison is. Getting in touch with district administrators and teachers can also be difficult, so the hurdles of even basic communication need to be overcome and channels for effective communication built. Finally, determine whether there are any university or school requirements to formalize the partnership.

Management
Who will be the point person in charge of communicating with potential partners? The person chosen for this task should understand the cultures and the methods of getting business done in both the university and the schools. The cultures and constraints found in each arena are different. The point person also needs to have a good understanding of the potential impacts (including both costs and benefits) that the proposed project has on the university, schools, and teachers so that the project can be “sold” to prospective partners.

Communication with Schools
Many GK–12 PIs become frustrated when they try to contact schools and hear nothing in return. There are a number of understandable hurdles to get over. Emails are sent to superintendents or principals, and flyers are sent to schools to recruit teachers, and often no one responds. This tends to happen when the schools are located near a university and are bombarded with requests by outside groups, especially a neighboring university, and it may be inefficient to respond to all of them. In addition, most school districts have highly restrictive filters on their incoming email, so administrators or teachers may never receive the message. Phoning schools can also be problematic, because administrators are rarely at their desks and teachers are usually busy (if they even have phone access) from 7:00 A.M. to 3:30 P.M. or beyond. Of course, leaving a message is always a possibility, and if you have not heard back in a few days, try calling again. Often, an effective first step is to set up a face-to-face meeting with the appropriate school personnel. This meeting then lays the groundwork for future communication.

Chapter 3 offers suggestions on how to recruit teachers into the project and tips for communicating with schools. Note that accumulating experience with each district is the best way to learn how to communicate with your potential school partners.

Formalizing Partnerships
You will need to check with various units on your campus, potential school partners, and funding agencies to determine whether formalized agreements are required when you develop partnerships. Often, schools will request a memorandum of understanding (MOU) to initiate a long-term partnership with a university. Also, the university’s Office of Human Research or Office of Sponsored Projects may want documentation to formalize the university’s work within a K–12 school. Sometimes, the MOU may require the superintendent of the school district to write a letter of support confirming the responsibilities of the district in the partnership. Such a letter helps to provide a template from which the superintendent can work.

KEYS FOR SUCCESS

- Make sure that the establishment of a partnership is a high priority at the university and that a plan is developed for attaining successful partnerships.
- Communicate with schools and teachers through persistence and multiple modes of connection.
- Use established projects both at the schools and within the university to find partners and eager participants.
- Clarify the benefits and responsibilities to everyone involved in the partnership.

NEXT STEPS
Working from the Top Down
After identifying possible partner school districts and teachers, it is time to establish the partnerships.
Working from the top down in a school district makes it more likely that the partnership will develop and run smoothly. If you start at the top of the school district's administration—that is, the superintendent—then an email and a letter with a request for permission to work with the school district's principals to bring your project into the district will usually be successful. Be explicit in the letter: Explain what the project is and the benefits it will have for the district's teachers and students. If your project involves inserting new curriculum into the district's established and approved curriculum, be sure to demonstrate how the new material aligns with state standards and district learning objectives. Superintendents are busy people, so one option is to include in an email or a letter a phrase that says something like “If this meets with your approval and I do not hear back from you, I will be contacting the following school principals....” Doing this takes one thing off the superintendent's to-do list if he or she approves of your working in the district. Often, superintendents trust principals to be the gatekeepers for what happens in their schools.

Principals are also busy people, and they can be very protective of their teachers and students. They will want assurances that your project is going to have a positive impact on all parties and that it is not just for the benefit of the university. Sending a letter and an email introducing your project and requesting input from principals regarding which teachers to contact is a good way to get the conversation started. You should also mention that you have been in touch with the superintendent and have his or her approval.

Principals often ask for a phone conversation or meeting to discuss the project and to get firsthand knowledge of who is involved. A face-to-face meeting with the principal can get all parties on the same page very quickly. This is also an opportunity to get some very good “insider” information and explicitly discuss what type of teacher should be involved.

It is hard to generalize about what makes for a good K–12 partnering Teacher, but here are some of the qualities projects have looked for to achieve successful partnerships:

- Has at least five years of teaching experience,
- Has been teaching the same content for at least three years,
- Has a desire to learn or enhance inquiry-based teaching,
- Shows an interest in mentoring (has mentored new teachers, has taught student teachers, etc.),
- Has an understanding that teaching is a lot about teaching children rather than teaching content,
- Makes it a priority that students enjoy learning,
- Has the time to support the work of a Fellow.

Working from the Bottom Up

If informal discussions of possible participation with teachers in a school have already taken place, be sure to mention this to the principal, especially if the teacher may already have spoken to the principal about his or her desire to participate. It is fine to recruit teachers informally, but always mention that you need to first get approval from the school administrators. Having an informational meeting with potential teachers, either prior to or after you receiving funding, is a good way to gauge the needs and desires of possible participants.

When talking with teachers, make sure that you lay out all of the benefits of participation for both them and their students. Also, be sure to discuss the responsibilities, especially the time that their participation will take. Time is a major consideration, and even with financial compensation for participating, teachers have only so much time each day. Teachers who coach three sports during the year, run the science club, and also have children of their own may not have the time required to devote to the project.

It is usually a good idea to have a formal application for teachers to complete (see Appendix 2.1 for an example). Use the application to get the basic information you need to contact the teacher, but also try to gain some insight into how the applicant views teaching and what his or her classroom is like. It also is advisable to make a classroom visit to see the teacher in action. Determine whether the classroom fits into the model in which you would like your university students working. Don't necessarily look for a specific type of teacher or classroom manager, but look for...
teachers who meet at least a minimum standard when you consider their overall view of teaching and learning. Fellows can learn a great deal by working with different types of people, and the lessons they learn will carry nicely into their professional careers.

Each school district has its own policies regarding developing partnerships with universities and the placement of noncertified people (e.g., the STEM graduate students) into classrooms. Ask what procedures to follow at all levels. Often, superintendents do not know that the district Human Resources Office has developed protocols for having such projects in their schools, so be sure to ask principals for guidelines, requirements, and contacts.

**WORKING COLLABORATIVELY WITH YOUR UNIVERSITY ENTITIES**

There are many units on the university campus that can help create the partnership foundation for your GK–12 project.

If your campus has a college of education, its placement staff can be valuable allies and collaborators. These are the people (or person) who place preservice teachers in schools. They have an intimate working knowledge of school districts and teachers and can assist in developing partnerships. They also can help with school district requirements, such as the need for having background checks performed on all of the university students who might be working with K–12 students.

Note that, historically, some GK–12 projects had a policy which stipulated that GK–12 Teachers could not have a student teacher while participating in the GK–12 project. Because this may cause some problems for the college of education in placing preservice teachers if you “take” all of their “good” teachers, be sure to communicate your intentions clearly and work collaboratively with the placement staff. This is not a problem in placing Fellows in elementary school classrooms, as there are many more elementary school teachers than there are grades 7–12 science and mathematics teachers in a district.

Other excellent collaborators in the GK–12 model have been K–12 outreach centers. If the university has a center, contact it early in the planning process. Outreach center personnel can provide many of the same resources and information that a college of education can supply.

**Proven Effective Practices in Various Situations**

There are many variables determining university and school district partnerships. Universities can be small or large, can be located in rural or urban settings, and may focus research broadly or on specific fields. School districts can be rural and small, with a single school housing K–12th grade and having only one science or math teacher, or huge and urban, with one school having 3,000 students and with all the science and math teachers available as partners.

In larger school districts, you can take advantage of the community of educators that already exists. In this case, it is best to find a teacher who comes highly recommended or is a known enthusiastic participant and ask him or her to recruit other good teachers for the project. This cadre can become the core of your Teacher collaborators. Also, school district administrators may allow time to present the project to all of the science or mathematics teachers during a professional development day. Consider gathering with interested teachers beyond that meeting to pursue the best partners.

In smaller districts or schools, with a limited number of teachers in any one subject, determine whether the teacher’s schedule is compatible with the needs of the project. For example, in cases where a teacher has five or six different courses to teach in a day, it may not be possible for a graduate student to master a lesson plan by teaching the same content lesson at least three times. To remedy this shortcoming, the graduate student may be able instead to work in multiple schools, but this approach presents other problems, including finding more than one partnering Teacher for each student.

Charter schools are other institutions that can present some unique opportunities. Often, charter schools have more flexibility in their curricula and therefore can accommodate working with outreach projects more easily. They also often pick a theme (e.g., “The Wonders of Water,” “Energy,” or “Ecology”) for an academic year, and all teachers in the school...
incorporate that theme into their unit plans. If the proposed project can provide “experts” to support the teaching and learning within a specific content area that is the focus of instruction of the charter school, the administration and teachers may jump at the opportunity for collaboration.

**Getting Buy-in From Everyone: Keys for Successful Partnerships**

A partnership must be collaborative, but should not be required, or just one more thing added on to everyone’s already busy schedule. All participants need to see the benefits of participating for themselves as well as for their “constituents” (e.g., students for teachers, teachers for principals, and schools for the superintendents). Everyone also needs to feel that they have input and influence on the partnership activities. There are some distinctive elements of the GK–12 model that are worth stressing in your initial discussions with school personnel that may make the model more appealing than ideas from other outside participants who may simply want to use the K–12 schools to accomplish a task. As the PI for the University of New England (UNE) GK–12 project stated,

“A strong partnership was developed ahead of time in seeking out the schools to explore ways in which the University could be of service. This firm foundation of reaching out to the schools and demonstrating an issue to be of service to them fostered immediate commitment on the part of six area school districts to support UNE in their GK–12 proposal.”

First and most importantly, GK–12 projects are partnerships between equal parties: They are not projects designed for the university faculty or graduate students to “fix” the schools and teachers; rather, they are partnerships with scientists and engineers (not education departments), and they are for the long-term, built around the idea that all parties in the partnership have plenty to gain from the project over time.

There are some straightforward ways in which you can develop positive relationships between universities and the K–12 community: bringing the K–12 leadership into the development of the project, having meetings with potential partnering Teachers to make them aware of the project and its benefits, and working within and for already established school projects, among others. The exemplars at the end of this chapter also provide some good insight into methods that have worked and ways to build positive relationships.

There can be tension when placing a person in a K–12 classroom, which is the teacher’s domain. As one GK–12 project administrator put it,

“The main component, we found, was mutual respect. It is a challenge for many of the Teachers to teach engineering—a subject they have never studied—and it is a challenge for our STOMPers (GK–12 Fellows) to teach (something most have never done.) In this way, we found lasting friendships/collaborations develop between students and Teachers, leading to a strong school tie.”

—Tufts University STOMP GK–12 Project

That strong partnership is the goal of any good outreach project between a university and the K–12 community.

**RECOMMENDATIONS**

- Develop partnerships prior to attaining funding so that partners have input into planning goals and objectives.
- Make sure that all parties know the responsibilities and benefits. Include university entities, such as the Office of Sponsored Projects and the Institutional Review Board, as well as the school district administration, including the superintendent, principals, and human resources.
- Bring the main partners together to share ideas and to get acquainted in order to establish good working relationships.
EXEMPLARS

TOP-DOWN TURNAROUND New Jersey Institute of Technology http://c2prism.njit.edu/
The C2PRISM project started selecting teachers by a top-down approach through the public school system. (At a single private school partner, this process also worked well.) Coming from the central district to the principals and then from the principals to the department chairs, information or enthusiasm sometimes was lost. In the first year, for example, three teachers from one of the partnering schools showed up for the opening event. They had been told to be at a certain place at a certain time. Thus, the teachers had not really even considered whether they wanted to be a part of the project. Although things eventually worked out, we asked for and received permission from the school district to conduct a search for teachers in future years by a much more direct approach. We worked through individual school department chairs to identify good candidates, and put flyers in the mailboxes of all science and math teachers at selected schools in the partnering district. We found that self-selection (i.e., teachers directly applying for positions in C2PRISM) enabled us to find teachers who were interested in working on the project. Of course, teachers still went through their administrations to gain the necessary permission and support. Note that a search for teachers isn’t the only way GK–12 Teachers were found: sometimes teachers who learned about Fellows in their schools or who were friends of participating Teachers found us.

WORKING WITHIN THE SYSTEM Arizona State University http://gk12.asu.edu/
Our story of working within the Tempe Union High School District is one that may be similar to the story of many new GK–12 projects. One of our project directors had worked previously with one of the teacher leaders at Tempe High School and had made the initial contact with that person. This teacher was enthusiastic about bringing the Sustainable Schools project to his school, and he recommended the project to his principal and a cohort of teachers, helping us along the way with connections at the district level. The Tempe Union High School District encourages teachers to bring projects to their schools, so this approach of working through teachers at a school was a model that they preferred. The administration at Tempe High School allowed its teachers to form a “Sustainability Professional Learning Community” through which our GK–12 Fellows connected with the appropriate teachers. Again, this was taking a structure already in place and using it for our project. The “Sustainability First at Tempe High” Project (SF@TH) set high standards that paved the way for our second year, where we are now working in six of the seven high schools and on broader district projects, including a yearly sustainability survey for students.

SCHOOL AS INITIATOR OF PARTNERSHIP East Tennessee State University http://www.etsu.edu/cas/gk/
Developing a partnership with a school is a long-term commitment by all partners to ensure that all key players contribute equally, to respect distinct cultures in the school and the university, and to empower all participants to take on leadership roles wherever appropriate. In the case of the partnership between East Tennessee State University (ETSU) and North Side Elementary (NSE), initial contact was made by the NSE principal who wanted to ensure the school’s success as a newly designated Signature School of Mathematics, Science and Technology. She believed that one of the first things to do was to form strong bonds with institutions of higher learning. We were quick to identify the NSF GK–12 project as presenting us with exciting opportunities for partnering. We asked one of the co–project directors and the science lab coordinator of NSE to contact the appropriate district superintendents and set up a meeting to explain the NSF solicitation and project. We actively involved superintendents, principals, and key teachers in the writing and planning of the NSF proposal. We solicited letters of support from key persons, including the superintendent, three senators and representatives, the ETSU president, provost, and dean of the graduate school. During the planning process, we held focus groups with the school’s teachers and were able, with support from three principals, to enjoy a near complete buy-in. In addition, teachers were able to participate at three different levels, allowing us to accommodate those who could commit only a small amount of time to the project.
THE SUCCESS OF A GK–12 PROJECT is heavily dependent on the quality of the people recruited, particularly the leadership, Fellows, and Teachers. In recruiting, it is fundamentally important for a GK–12 project to use active members of the community who are familiar with the goals, objectives, and expectations of the project. All members of the project can assist with this recruitment effort by disseminating information about the advantages and successes of the project within their own networks. In this way, they become strong advocates in the STEM research and education communities and can help identify suitable STEM graduate students, K–12 teachers, and schools.

To succeed in recruiting Fellows and Teachers, the GK–12 project leadership team must communicate the benefits of the project effectively to potential Fellows, research mentors, K–12 teachers, and schools. (See Chapter 12 for a detailed discussion of the evidence of the success of this model.)

RECRUITMENT
The GK–12 leadership is responsible for leading the recruitment and selection of the other project participants. Many projects form a selection committee that is responsible for identifying, recruiting, and selecting Fellows and Teachers. (Other projects rely on the project director alone to do the selection.) The selection committee can vary in size and may include the project director, at least one STEM faculty member, a GK–12 Teacher, and a GK–12 Fellow. Additional members might be a faculty member from the education department and an evaluator. For multidisciplinary projects, having representatives from the different disciplines involved is recommended, especially representatives from those areas of research included within the overarching theme of the project. Having former GK–12 Fellows and GK–12 Teachers on the committee provides an effective means of disseminating information about the success of the project and recruiting new Teachers and Fellows.

In order to recruit participants with the appropriate skills and potential, GK–12 projects must articulate and advertise their choice(s) of discipline(s), model format,
goals, objectives and expectations. Most GK–12 projects use websites to disseminate this information. They also use members of the GK–12 community as ambassadors, since GK–12 Teachers and Fellows are familiar with the project and can provide an authentic point of view for prospective new Teachers and Fellows who are interested in the project. GK–12 Teachers and Fellows are also familiar with the culture of their departments, schools, and universities.

**Recruiting University Faculty**

If a project is just starting out, the founding core team will most likely need to reach out and find other faculty to participate. Later, it might be useful to circulate new faculty onto the project team. To recruit new faculty members for the project, it is recommended that university administrators (the vice president of research, deans, and department heads) be briefed on the objectives of the project and the potential benefits that participation will have for all members of the university community. Having support from university administration will facilitate the dissemination of information and can help to identify suitable faculty members for the project. The strategies for recruiting university faculty are also helpful in obtaining the support of the research advisors of the GK–12 Fellows.

**Recruiting GK–12 Fellows**

Communication about open GK–12 Fellow positions should be sent by the leadership of the project to the deans of STEM colleges, to department heads, and to other university leaders. Such communication should also be sent to all graduate students in the discipline(s) involved in the GK–12 project. Other campus graduate student communities, including the graduate student government, departmental professional societies, and campus organizations that serve under-represented minorities in STEM education (such as the National Society of Black Engineers; the Society of Hispanic Professional Engineers; and the Society for the Advancement of Hispanics/Chicanos and Native Americans in Science), can help with this dissemination and advertisement effort. All communications, from email to flyers, should contain the link to the project’s website, along with information about the requirements and expectations of potential Fellows. Efforts should be made as well to distribute information to any partnering minority-serving universities. Past and current Fellows should be enlisted to help spread the word to their labmates and other peers. The research advisors of past and current Fellows also are a good resource for disseminating recruitment materials to their colleagues.

**Recruiting Teachers and Schools**

Once the partnering schools have been chosen for the project (or for an ongoing project that you are preparing to expand at a given school), it is important to recruit Teacher participants. Once you have the support of the school administration, it is best to promote the project throughout the school year to potential Teachers. GK–12 project leadership, research mentors, Fellows, and current GK–12 Teachers (from the ongoing project) can all assist by visiting the schools regularly, using the educational materials produced by the project (e.g., lessons and labs) in the classrooms of other teachers, and incorporating these approaches in a variety of outreach activities, such as school visits, teacher training, after-school projects, and science clubs. In some cases, GK–12 projects offer teacher training prior to Teacher selection so that the lessons developed by Fellows and Teachers are disseminated and new Teachers are recruited for the project. GK–12 Fellows can also offer visits to their laboratory or field sites, and they can participate in presentations at partnering schools.

**EFFECTIVE STRATEGIES FOR RECRUITING FACULTY AND RESEARCH MENTORS**

- Build institutional support by offering presentations that highlight the success of your project to upper administration.
- Disseminate information about the benefits of the project to faculty through websites, the university newspaper, open research forums, and peer-reviewed articles.
- Disseminate information about project success at department seminars by highlighting the positive effects of the project on GK–12 Fellows (skills development, productivity, job search successes).
- Invite potential new faculty and research mentors to GK–12 meetings, school visits, and to participate in outreach efforts of the GK–12 project.
APPLICATION AND SELECTION
It is helpful to have information about the duties, responsibilities, and benefits for all members of the GK–12 community readily available online. In particular, as discussed next, application forms should include links to the lists of responsibilities and benefits, including stipends or other forms of compensation. Likewise, it’s helpful for Fellows and Teachers to understand the criteria by which their applications will be evaluated.

Application and Selection Process for Fellows
Applications for Fellows typically require information about the applicant’s academic background (some request official transcripts), reference letters, and short essays mentioning the applicant’s experience, interests, potential contribution to the project, and future career goals. It is important to balance the desire for information from the applicants with the need for an easy, short process that will not dissuade people from applying. (See Appendices 3.1, 3.2, and 3.3 for some sample application forms.) It is critical that the introduction to the application state the duties, expectations, and compensation for participating. Of course, the application packet

EFFECTIVE STRATEGIES FOR RECRUITING GK–12 TEACHERS

- Invite teachers and their students to university research laboratories and/or take them on field trips with the Fellows.
- Have university faculty and GK–12 Fellows offer informal scientific talks and/or role model talks at the partnering schools.
- Invite teachers to participate in GK–12 project meetings.
- Provide teachers with information about the benefits of the project for their institution and their own professional development.
- Offer summer research internships for teachers to work with the Fellows in order to familiarize them with the Fellows’ research and laboratory techniques.
- Offer professional development projects for teachers during the summer and/or academic year to familiarize the teachers with lessons and labs developed by the Fellows.
- Highlight the project goals and the requirements related to time and weekly or monthly routines.

EFFECTIVE STRATEGIES FOR RECRUITING GK–12 FELLOWS

- Disseminate information about the benefits of the project to potential GK–12 Fellows through websites, student newspaper, and signs around campus.
- Build support of research advisors by offering presentations that highlight project successes and positive outcomes for their institution to different academic units. (Get invited to faculty meetings, etc.)
- Disseminate information about new Fellow openings to campus organizations and groups that work with graduate students.
- Make presentations about the success of your project at graduate student organization meetings and highlight the positive effect that the project has on GK–12 Fellows (skills development, productivity, job search successes).
- Invite potential Fellows to GK–12 meetings, school visits, to participate in outreach efforts of the project, or even shadow a current Fellow.
- Visit nearby and partnering historically black colleges and universities and other minority-serving institutions to recruit their students in your project.
- Provide applicants with a clear understanding of what will be required of them (the amount of time being a Fellow or Teacher will take, the number of hours they will likely spend in the classroom, what their weekly or monthly routine will be like, etc.)
should also describe the selection process (key deadlines, what to expect, materials to be submitted, etc.). Usually, all applications are screened by the selection committee. Most GK–12 projects then interview the candidates, and some projects use standardized rubrics to rank the applicants. In those projects, the applicants receive an overall ranking based on their interview, qualifications, interest, potential, and ability to respond to questions. The actual requirements of the Fellows will depend on the GK–12 model used, the specific discipline taught in the project, and the target grade level in schools. Suggested characteristics for GK–12 Fellows are provided below.

In selecting GK–12 Fellows who are likely to be effective, it is important to think about the point at which each Fellow should be in his or her career. Because of the numerous responsibilities GK–12 Fellows have, many GK–12 projects require that graduate students not be taking many courses. Projects that focus on bringing the Fellows’ research into the classroom typically need Fellows to be fairly advanced in that research. Additional selection criteria can include maintaining a good academic standing (e.g., the Fellow has passed qualifying exams or otherwise advanced to PhD candidacy), having a supportive research mentor, keeping up an interest in science education, being open to constructive criticism, being able to work in groups, and possessing leadership skills. The most productive GK–12 Fellows are students who have the potential to learn and grow in the project, so it is critical that the selection committee focus on both the background and potential of the applicants. To probe your applicants’ potential for growth, it is recommended that you include questions in the interview which address typical situations encountered in carrying out the project. Some applicants who seem shy in the interview can actually benefit more from the GK–12 project than other applicants with outgoing personalities.

Perhaps even more important than determining an individual ranking or review for each applicant is examining how the potential participants can work together and create a balanced team of expertise, experience, and diversity.

Upon receiving word that they have been accepted into the program, Fellows often sign a formal contract indicating their own acceptance and their willingness to perform the duties of the project. Such a contract may include conditions for dismissal from the project. It is also a good idea to require a signature from the GK–12 Fellow’s research advisor to signal an understanding of the project commitments.

**Application and Selection Process for Teachers**

The method you use for selecting GK–12 Teachers will depend on the model you apply to your project. Some projects use formal applications and interviews; in those cases, the process just outlined for Fellows can be followed. In other projects, a lead Teacher will work with the project director to help identify potential Teacher candidates. Usually, there is no formal application process in these cases, but rather an informal conversation about the expectations and benefits of participating. Some project models are completely open: Any Teacher may participate simply by inviting a Fellow into the classroom (on a one-time or an extended basis). Generally, those projects which pay a stipend to the participating Teachers have more formal application and selection processes than those which pay a single lead Teacher coordinator from the school (who is usually named at the time the school is chosen).

In selecting GK–12 Teachers, it is important to think about the level at which the prospective Teachers are in their careers and try to assess their willingness and ability to mentor a STEM graduate student. Then it is necessary to provide them the opportunity to present STEM content in their classroom. In many cases, brand-new teachers are too overwhelmed to accommodate yet another person (the GK–12 Fellow) in the classroom asking for their time and attention, and teachers near retirement are sometimes less adaptable or unwilling to learn new pedagogical and science skills. Keep in mind that these are generalizations and some projects have had outstanding results with both new teachers and teachers nearing retirement. Sometimes, because of the specific design of the project, teachers are
QUALITIES OF SUCCESSFUL GK–12 FELLOWS

- Be able to teach, or be interested in improving teaching skills, and be interested in presenting STEM to K–12 audiences.
- Have good time management skills, or at least an understanding of the need for, and an interest in, achieving these skills.
- Be able to collaborate with different types of people.
- Be able to do independent work.
- Have time to be in the classroom, and have a research advisor who understands the responsibilities of being a GK–12 Fellow.
- Be willing and available to participate in summer training and monthly meetings (if applicable).
- Be willing to be responsible and professional, to complete all forms with information (about teaching, scheduling, meetings, etc.) on time, and to communicate with all parties.

QUALITIES OF SUCCESSFUL GK–12 TEACHERS

- Be able to teach in the discipline, grade level, and type of school appropriate for the project (e.g., middle school or rural schools).
- Be willing to co-teach with the Fellows (not use the Fellow's presence as an opportunity to "check out," and not be afraid to have the Fellow help in the instruction mission).
- Be able to use, and be interested in using, Fellows in classes as resident mathematicians or scientists, not as student teachers.
- Have strong pedagogical training or a willingness to work on pedagogical skills, and be able and willing to work with Fellows on lessons.
- Be willing to participate in summer training to embrace new methodologies and technologies when appropriate, and to use the GK–12 materials developed for the project.

Some projects wait for all Fellows and Teachers for a given year to accept their positions before assigning Fellows to their partnering Teachers or schools, to ensure that the teams are formed according to the project's goals. The actual process used to determine the placement of the Fellows into the schools depends on the model used for the project. In some cases, placement is decided by the project director; in others, it is done as a community, with the GK–12 Teachers and Fellows working together during the summer as a larger group and then stating their preferences as regards the teams they want to join. Clearly, it is important that all the participants be aware of whatever process will be used in their placement.
In the first month or two of the year, project staff visited potential Fellows. This approach helped staff identify applicants with the right social skills. Then, we held staff meetings to review applicants’ credentials, weeding out those with weak or inappropriate backgrounds, questionable motivation, and personalities that would probably limit their effectiveness in the classroom.

Next, the remaining candidates had private interviews with the project staff. During the interviews, we clarified issues raised by the candidates’ applications, explored the motivations of the applicants, and explained our expectations. We reached a consensus regarding which graduate students were hired into the project.

Teachers were selected with equal care. The expectations for their involvement with the project were explained. The few who did not function as desired by project staff were released.

To present the Fellows to the students, we created a short video in which Fellows introduced themselves and discussed what they do as graduate students and how they got interested in their respective disciplines. The video was shown to the class by the assigned Teacher before the Fellow went to the school.

GK-12 Fellows were called “Resident Scientists,” “Resident Mathematicians,” or, alternatively, “Fellows.” Within a few months, all became role models in the eyes of students, including Fellows who made only occasional visits to certain classrooms. It was made clear to both Fellows and Teachers that the Fellows were not student teachers or aides. They were science consultants who actively engaged with the students and the Teacher.

New Fellows (selected in the spring) were asked to shadow an experienced Fellow for a few class periods in the spring. A new team of Fellows was selected each year so that the benefits to graduate students could be more widespread. However, we retained two to three of the most effective Fellows in a given year to serve a second year. They provided crucial experience, advice, and role modeling for the new Fellows.
SUCCESSFUL IMPLEMENTATION OF SCIENTIST–EDUCATOR PARTNERSHIPS REQUIRES A GOOD PLAN, clear expectations for participants, infrastructure to support the teams, a strategy for communicating successes, leadership to make sure that the Fellow–Teacher teams are working effectively together, and the tools to succeed (Appendix 4.1). In addition, it is important to identify benchmarks for the success of the project, both to make the project better over time and to report on its successes and achievements.

This chapter focuses on developing the skills for participants so that they will be successful in their work. In particular, the chapter looks at project management and logistics; the possibility of offering training workshops, institutes, and courses; and introductory ideas to plan for project assessment.

MANAGEMENT AND LOGISTICS

Project Coordination

Successful partnership projects have a plan for managing project elements and people—including one or more staff members at the university employed as a project coordinator—and the appropriate infrastructure and means to manage the project. A useful tool for visualizing how all the project elements in the plan fit together, and for aiding communication about how a GK–12 project works, is a project flow diagram (Figure 4.1). Typical elements include recruiting, mentoring, school year activities, training meetings, and assessment. Such a diagram helps the implementation team focus on project core elements and how they are linked to desired project outcomes.

Many GK–12 projects have utilized a project coordinator as a liaison among participants and to ensure smooth and timely operation of all elements. On a large number of the GK–12 projects, the project director has also served as the project coordinator. Other projects have hired a staff person to play this role. Depending on the size of a partnership project, a coordinator might be a full-time staff person or a part-time graduate student assistant. The kinds of duties typically assigned to a coordinator include assisting with graduate student and Teacher recruitment, organizing training for all project participants, keeping a project calendar, organizing special events, assisting with project assessment, developing newsletters and other communications, and coordinating project records. Project
Figure 4.1 - Project Plan from the University of Montana ECOS GK–12 Project Illustrating Linkages Among Project Elements

Retention and Mentoring of Fellows and Teachers (Yearlong)
- Team mentoring
- Science partnership seminar
- Faculty and graduate student mentor training
- Luncheons for Fellows and research advisors

Recruitment
- Graduate students in environmental sciences
- Teachers from partner K–12 Schools
- Notification of all participants

Sample Content Workshop Topical Areas
- Unifying ecological themes
- Forming partnerships with scientists
- Developing school ecology outdoor laboratories
- Tools and techniques for ecological sampling
- Authentic assessment for science

School Year Activities of ECOS Teams at Partner Schools

Schoolyard
- Approval of any site modification plans
- Set up study areas
- Begin guided inquiries to learn sampling and data collection techniques
- Implement open inquiries of student design
- Continue inquiries through academic year
- Implement plan to take care of sites over summer

Classroom
- Shadow teachers for 1 month
- Assess technology capabilities; plan for connecting classes to project website
- Teach ecological concepts related to schoolyard labs
- Develop curricula and link to standards
- Work as tutors for student projects

Capstone Opportunities (Late Spring and Summer)

K–12 Students
- Presentations at ECOS Project symposium, science fair, &/or community groups

ECOS Team Fellows
- Dissertation chapters
- Presentations at scientific meetings

Partner Teachers
- Presentations at scientific and education conferences

University of Montana GK–12 Project Outcomes
- Sustainable partnerships between scientists and K–12 schools
- Assessment data that inform the project and the field about implementation of partnership projects
- Web-based library of curriculum modules that link ecology to local schoolyards
- Web-based Natural History Guide to Local Organisms
- Set of communication tools, including ecological calendars and newsletters, to share accomplishments of the project
- Articles for project dissemination in peer-reviewed journals and presentations at research conferences
- Cadre of scientists with the skills and dispositions to work effectively with local schools wherever the scientists’ future careers take them

Fellow Training (Jan—May)
- Teaching science
- GK–12 seminar

Summer Workshops (July & August)
- Implementation planning by project directors, staff, and lead teachers (year 1 only)
- School year implementation plans developed by ECOS Teams and partnering Teachers (all years)
- Writing workshop for project dissemination (all years)
coordinators also are available to answer questions and point graduate students and Teachers to resources to help them be successful in the classroom.

Having a dedicated project coordinator helps to ensure timely communication, accurate dissemination of information, insight into how the teams are functioning in the partner schools, and accountability with respect to project goals and objectives.

The number and kinds of schools that are part of a partnership project influence management strategies and project logistics. A project may, for example, select one focal school or choose to work with all of the elementary schools in a district or region. Some projects may work with schools across the K–12 spectrum. Working with a Teacher who is already recognized as a leader in STEM education among his or her peers and the education community can help GK–12 project leaders navigate the different cultures in elementary, middle, and high school settings. A lead Teacher also can help project leaders identify key STEM needs in a given school and facilitate communication with school leaders, Teachers, and staff.

**Project Steering Committees/Advisory Boards**

Depending on the size and scope of a project, it may be useful to create a steering committee and/or an advisory board. A steering committee is usually composed of “local” members representing the key constituents of a project. In the case of a GK–12 project, the committee might include project directors or codirectors, representative administrators from the university or college and the participating schools (e.g., department chair, principal), a representative from a school or college of education, Teachers from the target grade bands, and/or graduate students. The typical role of a steering committee is to define policies, administer the student internship and scholarship projects, select partnering schools and Teachers, and ensure timely implementation of the project. Steering committees also are very much involved in oversight of the day-to-day operations of the project and meet regularly to plan activities, review project assessment data, accomplishments, and challenges, and communicate about the project.

Some projects engage an advisory board instead of a steering committee. An advisory board is often composed of individuals with a more global view of implementing STEM partnership projects and may include senior-level administrators from the university and school district (e.g., a dean and the superintendent), individuals who have successfully implemented similar partnership projects, a local community leader or donor, and other individuals with relevant experience. Advisory boards typically meet with project leaders once or twice a year to review the implementation of the project and to provide advice and insights on how to best meet the goals and objectives. Sometimes advisory boards are tasked by funding agencies to provide independent oversight reports on project successes, challenges, and accomplishments.

**Communicating Expectations and Responsibilities with Project Participants**

The expectations and responsibilities of all individuals in a GK–12 project are dependent on the GK–12 model used. However, a strong project has well-structured roles and responsibilities for the various stakeholders. The project should establish

“It is an unfortunate shortcoming of graduate education that we provide our students so little real training in teaching. These Fellow–Teacher partnerships are a great way to fill that huge void, and at the same time provide new energy to graduate students to pursue academic careers”

—Ecology Professor, University of Montana
open communication between all members of the community, and the critical areas of the project should be evaluated regularly so that the project can be improved with time. The roles and responsibilities of Fellows, Teachers, their respective mentors, and education consultants are summarized as follows:

1. **Fellows’** responsibilities may include (a) devoting as many as 15 hours per week toward education activities, such as offering workshops, laboratory visits, field trips, and Teacher training, depending on the GK–12 model used; (b) preparing educational lessons related to their research and/or the discipline of the project; (c) attending summer and semester-long trainings and meetings; (d) working on a team with one or more Teachers at one or more assigned schools; and (e) submitting reports and any other documentation required by the project. It is important to note that Master’s and PhD students should maintain their research activities throughout the Fellowship experience. An Abt Associates evaluation (2010) of the GK–12 Program found that Fellows were able to maintain their research activities and experienced no delays in the time it took them to complete their degrees.

2. **Teachers’** responsibilities may include (a) working with one or more assigned Fellows in the development and implementation of lessons; (b) working on a team with one or more Fellows; (c) attending summer and semester-long training activities and meetings; (d) submitting reports and any other documentation required by the project; and (e) completing a laboratory or field experience at a Fellow’s research site.

3. **Research advisors’** responsibilities may include (a) assisting Fellows in the preparation of educational materials by providing feedback on scientific content and relevance; (b) mentoring Fellows in the development of scientific writing skills; (c) contributing to Fellow–Teacher team training (with scientific talks, role modeling, and/or school visits); and (d) attending key meetings of the Fellow–Teacher team training project.

4. The **educational consultant** is a person experienced in education and/or a retired teacher who monitors the progress of Fellows and Teachers in the implementation of lessons. Consultants meet with Fellows and Teachers regularly, provide feedback on educational activities, and make visits to the classroom. In the event that the project coordinator has the necessary expertise, he or she may also serve as the education consultant.

Different GK–12 models might require different responsibilities. It is important that the leadership, in collaboration with the committee, clearly establish the specific roles and responsibilities of Fellows, Teachers, and research mentors and provide training and mentoring for Fellows and Teachers, in order for the project to be successful. In addition, it is important for Fellows, Teachers, and research advisors to be adequately compensated for their involvement. In the case of the Fellow and Teacher, the compensation could be in the form of monetary support and/or graduate credits.

Table 4.1 shows the most common activities that Fellows engage in during their Fellowship experience. The table includes data from the Evaluation of the National Science Foundation’s GK–12 Project (Abt Associates, Inc. 2010). A total of 1,456 Fellows responded to the survey.

**Engaging Research Advisors**

Because STEM graduate students are a key component of GK–12 partnership projects, it is important to engage their research advisors in order for projects to be successful. Advisors need reassurance that participation in a GK–12 partnership project will not have a negative impact on the ability of the graduate students they advise to meet departmental and university requirements.
for timely progress toward the completion of their degrees. Communication with research advisors about the expectations for GK–12 Fellows should begin during the recruitment and application processes. For example, the GK–12 project at the University of Montana required a Fellow, her or his research advisor, and members of the Fellow’s graduate committee to collectively read and sign a contract that outlined expectations for the Fellow regarding participation in the GK–12 project (Appendix 4.2).

GK–12 projects have found many innovative ways to engage research advisors. Hosting a luncheon for Fellows and their advisors and asking Fellows to make presentations is one effective mechanism for keeping advisors apprised of the work of their students in local schools. Some projects have hosted field trips to the Fellow’s lab to meet the research advisor and the lab staff and learn more about what it means to be a scientist and to do science. Other projects have invited research advisors and lab colleagues to community service days at their local schools to work with Teachers and students or to help improve the school infrastructure for teaching science. Ultimately, it is important to seek feedback from research advisors to better understand how the GK–12 experience is affecting their student and to address issues as they arise. (A sample questionnaire for advisor feedback is shown in Appendix 4.3.) Advisors should be asked to play an active role in the partnership, both in supporting the work of their graduate students and in creating opportunities to further enhance university–school partnerships through the GK–12 project.

Engaging Community Partners
It is likely that there are many excellent resources in every community that can be included in partnerships to enhance STEM education. Beyond the graduate students and the labs they represent, most universities and colleges have a rich array of resources and individuals that may play a role. Examples of these resources are museums; centers for teaching and learning; schools and colleges of education; and other STEM undergraduate and graduate students, staff, and faculty. In many communities, individuals from government agencies with a science mission can offer access to resources and exciting field trip opportunities. Agencies that have complemented the work of GK–12 teams in schools include the Forest Service, Park Service, Agricultural Extension Offices, Fish and Game Agencies, NASA, and the National Oceanic and Atmospheric Administration (including the National Weather Service). Many GK–12 projects also have engaged local individuals and businesses. For example, the University of Montana ECOS project worked with local construction businesses and parents to construct nature trails and outdoor classrooms on the grounds of several partner schools. Many local businesses donated materials and labor to help build these facilities.

PREPARING TEAMS TO WORK TOGETHER THROUGH WORKSHOPS, COURSES, AND REFLECTIVE PRACTICE
Successful Fellow–Teacher partnerships can be challenging to achieve, so it is important to provide varied opportunities for team members to build rapport and to develop a common vision for collaboration (Caton et al. 2000). Many GK–12 projects have brought team members together in workshops and courses to develop highly effective partnerships. Creating workshop and course environments that stress equal status for Teachers and research

<table>
<thead>
<tr>
<th>Description</th>
<th>Percent of Fellows Performing Activity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presented lessons/lectures to K–12 students</td>
<td>92</td>
</tr>
<tr>
<td>Designed new inquiry-based lessons, activities, or modules for use with K–12 students</td>
<td>89</td>
</tr>
<tr>
<td>Led small-group activities/discussions with K–12 students</td>
<td>83</td>
</tr>
<tr>
<td>Modified existing lessons, activities, or modules for use with K–12 students</td>
<td>81</td>
</tr>
<tr>
<td>Planned, coordinated, and/or facilitated inquiry-based learning activities for K–12 students</td>
<td>77</td>
</tr>
<tr>
<td>Demonstrated scientific procedures, tools, and techniques in a K–12 classroom</td>
<td>77</td>
</tr>
<tr>
<td>Developed educational resources (e.g., lab equipment, software, books, websites)</td>
<td>62</td>
</tr>
<tr>
<td>Helped K–12 Teachers understand and use technology (e.g., computer software)</td>
<td>52</td>
</tr>
<tr>
<td>Planned, coordinated, and/or led student field trips or excursions for K–12 students</td>
<td>44</td>
</tr>
<tr>
<td>Developed and provided professional development to Teachers</td>
<td>39</td>
</tr>
<tr>
<td>Other</td>
<td>46</td>
</tr>
</tbody>
</table>

SOURCE: ABT ASSOCIATES 2010. NOTE: PERCENTAGES DO NOT SUM TO 100 BECAUSE RESPONSE CATEGORIES ARE NOT MUTUALLY EXCLUSIVE AND RESPONDENTS COULD CHECK MULTIPLE RESPONSES.
scientists (as recommended by Feazel and Aram 1990) and promote the two-way exchange of ideas and expertise is key to building successful partnerships and collaborations between scientists and K–12 Teachers. Moreover, working together on engaging inquiries and investigations which use low-tech materials that are easily available to Teachers can help all team members overcome their reserve and establish a personal basis for collaboration. During these meetings, participants learn strategies for collaborating in the classroom and beyond. They also work together to explore discipline-specific sampling methods, data collection protocols, data analysis, pedagogies, and curricula that are informed by the National Science Education Standards (Table 4.2, NRC 1996), the Standards for Mathematical Practice, and the National Educational Technology Standards. Note that at the time of this publication the Next Generation Science Standards (NGSS) were in the process of being developed and should be available in the spring of 2013. Once completed, the NGSS should be used as a guide.

Participants’ meetings can last for just a few hours or an entire semester, depending on the needs of the project and the aptitudes to be developed. An effective approach for training is to offer one or two weeks of workshop training in the summer, followed by daylong workshops several times during the academic year. The template for the work of the teams is developed during the summer sessions. The meetings during the academic year provide opportunities to develop new skills and knowledge, share the experiences of teams in the schools, and make changes as needed or desired.

### Summer Planning Workshops

An ideal time to bring Teachers and Fellows together is during the summer before they will work together in a classroom. Many GK–12 projects around the country have brought Teachers and Fellows together for one to two weeks (in one or two sessions). Summer workshops provide an ideal opportunity to share information on the goals and objectives of the partnership project, clarify expectations for all participants, explain policies and project requirements, and plan the activities of the teams for the coming academic year.

Summer meetings are also the best time for all of the participants to get to know each other and to build relationships that will allow them to work together successfully in the classroom setting. GK–12 projects have used a variety of strategies to get their summer workshops off the ground. Some projects

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**Elements for a Successful Planning Workshop**

- Enthusiastic, knowledgeable, respectful, flexible, friendly leaders.
- Clear objectives, excellent examples, and a detailed agenda (that is followed).
- Concrete ideas that can be used immediately.
- Research that supports applications.
- Lots of interaction and a variety of activities.
- Demonstrations of ideas and strategies, with relevant classroom examples.
- Time for participants to share their relevant experiences and insights.
- Time for participants to develop an implementation plan for the coming year, including an activity timeline, necessary resources, and a resource acquisition plan.
- A comfortable and appropriate meeting room and breaks (with food and beverages).
- Excellent visual and written materials, including a workshop packet with agenda, informational materials, forms, a reading list, examples, etc.

**Source:** SHARP 1993.
Table 4.2. Examples of How GK–12 Partnership Project Activities Can Align with the National Science Education Standards

<table>
<thead>
<tr>
<th>Teachers of science...</th>
<th>GK–12 Project Alignment with Standards for Teaching</th>
</tr>
</thead>
<tbody>
<tr>
<td>A) ... plan inquiry-based science project for their students</td>
<td>Teachers work with graduate student partners to develop inquiry-based research projects for their students.</td>
</tr>
<tr>
<td>B) ... guide and facilitate learning.</td>
<td>Teachers and graduate student partners provide opportunities for students to ask and research their own questions, with an emphasis on mentoring and advising.</td>
</tr>
<tr>
<td>C) ... engage in ongoing assessment of their teaching and of student learning.</td>
<td>Teachers and graduate student partners work together to develop and use diverse methods of assessing student understanding appropriate for the research projects.</td>
</tr>
<tr>
<td>D) ... provide students with the time, space, and resources needed to learn science.</td>
<td>Schoolyards and other local areas are explored as research sites to allow yearlong investigations by students using field and equipment and materials.</td>
</tr>
<tr>
<td>E) ... develop communities of science learners that reflect intellectual rigor of scientific inquiry, and attitudes and social values conducive to science learning.</td>
<td>Student-centered research projects reflect the variety of skills, interests, and ideas of all students. The Teacher–scientist partnership project models scientific collaboration and the science process skills essential to inquiry.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Professional development requires...</th>
<th>GK–12 Project Alignment with Standards for Professional Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>A) ... learning essential science content through the perspectives and methods of inquiry.</td>
<td>Teachers are mentored by scientists with strong science backgrounds, in the context of inquiry-based investigations. Teachers learn about the latest advancements in the science and technology fields, to better represent the scientific community to their students.</td>
</tr>
<tr>
<td>B) ... integrating knowledge of science, learning, pedagogy, and students; it also requires applying that knowledge to science teaching.</td>
<td>Through the development of inquiry-based research projects mentored by scientist team members, Teachers concurrently are exposed to scientific content and processes, as well as enhancing their skills in facilitating learning through the use of inquiry. Teachers apply that knowledge directly as projects advance.</td>
</tr>
<tr>
<td>C) ... building understanding and ability for lifelong learning.</td>
<td>A GK–12-like model provides intensive, yearlong participation in professional development activities and exposure to science culture, and opportunities for acquiring knowledge and experience.</td>
</tr>
<tr>
<td>D) ... projects that are coherent and integrated.</td>
<td>A GK–12-like project can provide coordinated professional development opportunities with a common goal of enhancing inquiry-based science opportunities for all students. Collaboration throughout the districts will build a vital network of innovative science Teachers.</td>
</tr>
</tbody>
</table>

SOURCE: NATIONAL RESEARCH COUNCIL 1996.

have engaged Fellow–Teacher teams in daylong open scientific investigations during which the team comes up with a researchable question, collects and summarizes data, and makes a presentation to the workshop group. Other projects have built trust and camaraderie through participation in an “adventure ropes course.” The key is to design an engaging introductory activity that focuses the participants’ attention and builds trust and rapport among team members and between the teams and project leaders.

Projects have also used a variety of approaches in matching Teachers with Fellows. This is an important component that should not be overlooked. The partnership between the Teacher and Fellow is key to success. Speed dating is one way projects have identified successful Teacher–Fellow matches. As part of the speed-dating process, each participating graduate student designs an activity around his or her research topic. Over a day or two, Teachers rotate through the graduate students, engaging in each of the activities with each graduate student. Alternatively, the situation could be reversed, with the graduate students rotating through the Teachers and the Teachers developing the activities. Either way, the process provides an opportunity for Teachers and Fellows to get to know each other, including their personalities and work habits. At the conclusion of the speed-dating exercise, each Teacher is asked to privately identify the three Fellows they would work best with and the Fellows are asked to do the same. The project management team then uses these rankings to pair the Fellows.
with Teachers. Other projects have used in-depth, one-on-one interviews of Teachers and Fellows to pair them properly. Regardless of the method used, it is important that sufficient attention be paid to the matching process and that the matches be made as early as possible. The sooner the Fellow and Teacher begin working together, the sooner potential issues can be resolved.

During the summer workshop, project staff also work with Teachers and Fellows to identify STEM content themes that link to the curriculum standards the Teacher must meet in a given academic year (especially with regard to benchmarks and learner competencies), as well as to the National Science Education Standards (NRC 1996, Table 4.2). The teams typically choose a set of inquiry-based learning experiences and then plan how they will coordinate instruction for the upcoming academic year. Graduate students are challenged to develop elements of the school year activities that relate to their scientific research background and knowledge. It can be helpful to include experts in curriculum development and pedagogical innovations from on and off campus to assist project participants with planning. Typically, teams also develop strategies for effective age-appropriate instruction (e.g., AISES 1995, NRC 1997) and plans for appropriate assessment, including examples of rubrics and alternative formats for assessing student performance. In addition, they may plan to use technology to support student learning.

Because these training sessions involve significant learning, many GK–12 projects offer academic credit for Teacher participation. Credit can be in the form of university or college credit hours and/or professional training hours for Teacher recertification purposes. A university extended education office can usually provide advice and administrative assistance for offering both kinds of credit.

**Curriculum Development**

A key effort, both during summer workshops and over the course of an academic year, may be developing and adapting STEM curricular materials to use in the classroom. There is no shortage of materials or approaches that a project might use to get started. Sample resources are listed in Appendix 4.1. A good starting place is to review the National Science Standards (NRC 1996) and the accompanying materials on achieving science literacy (NRC 1998). Also, the special feature “Learning to Read and Reading to Learn” (Science, April 23, 2010) provides an excellent collection of articles reviewing literacy in science.

The most effective STEM instruction takes a “learner-centered” approach, to make sure that we focus on students while we are teaching science. Once a team has decided on a topical area, what is involved in developing an effective unit for a K–12 classroom? First, it is important to decide what a student in a particular grade should know and be able to do by the end of the instructional unit. Second, it is important to determine what proficiency, or mastery, looks like for a student in the targeted grade. Third, teams should decide what evidence they will accept which indicate that the student has actually mastered the content and skills in the unit.

Regardless of the level of instruction, a very useful model for developing curricula is the “backward design” described by Wiggins and McTighe (2005). This model works equally well for the K–12 classroom or the university course. The design of student-centered units begins with defining clear and
measurable learning goals. Next, assessment tools are devised that are appropriate for evaluating the extent to which the learning goals were met. The third step is to plan the instructional strategies that will best help students meet the learning goals. In the K–12 setting, it is important to minimize lecturing to students and to create as many opportunities as possible for students to engage in active learning. The curricular materials developed by Fellow–Teacher teams can become a valuable resource for the broader educational community. Having GK–12 teams use a standardized format for the curricular materials they develop will make it easy for other Teachers to use them and for a GK–12 project to disseminate them widely. A sample unit format is shown in Appendix 4.4.

**Culture and Diversity**

Culture and diversity are also important things to consider in preparing for team success. Many dimensions of diversity, inclusion, and cultural competence are relevant to establishing and sustaining GK–12 projects and the Fellow–Teacher team. For the purposes of this guide, diversity refers to acceptance and respect toward individual differences, regardless of race, gender, socioeconomic status, age, physical ability, religious belief, cultural background, sexual orientation, or political perspective. In implementing various phases of the GK–12 collaboration, whether between the K–12 schools and the university, the schools and the community, or the Fellow and the Teacher, an essential first step should be to assess the demographics of the K–12 student and Teacher population, as well as the student and faculty population at the university.

The GK–12 project is an ideal vehicle for enhancing diversity across institutions. A number of institutions used their projects to increase the diversity of their pool of graduate students through recruitment efforts. In addition, many colleges and universities implementing a GK–12 model chose to target K–12 schools that serve primarily underrepresented or economically disadvantaged children. Placing Fellows who are typically much closer in age and cultural background to K–12 students can bring about positive results. The students then find themselves looking at graduate students as academic role models and begin feeling that they, too, can one day break stereotypes and become a graduate student pursuing a STEM degree. According to Abt Associates (2010), 94% of K–12 students participating in the GK–12 project experienced an increase in interest and excitement about learning mathematics and science at school.

Fellows and Teachers may differ on many of these dimensions. Fellows and K–12 students may also come from very different backgrounds and other characteristics. Whether in recruiting diverse Fellows and Teachers, preparing Fellows for inclusive instruction, or considering a culturally sensitive curriculum, taking into account diversity and inclusion is essential to many projects.

**Supporting Teams Through Graduate Courses and Seminars**

A clear benefit of participating in a GK–12 project is that Fellows are able to bring cutting-edge science to K–12 classrooms.

But many GK–12 Fellows report that they also profit substantially in terms of developing their
teaching skills. GK–12 projects can support the professional development of their Fellows and Teachers by offering academic courses and seminars focused on innovative instructional pedagogies, the latest educational research on teaching and learning, elements of successful partnerships and the most effective collaborations between Teachers and scientists, issues pertinent to K–12 learners, approaches to learning of students of different ages, and strategies for assessment. In these seminars and courses, participants can (1) develop effective teaching strategies for diverse students; (2) review the literature related to instructional management techniques, science education and the current reform movements, and the use of technology in the classroom; (3) develop innovative guided-and open-inquiry investigations; (4) present an innovative instructional unit in a classroom setting; and (5) use classroom-based research methods and assessment techniques to ensure that their teaching is well connected with student learning. Such courses and seminars also provide opportunities to develop practical skills and tools that will help the participants in future academic positions, including articulation of their teaching philosophy, learning and practicing time management techniques, developing communication skills, and preparing a professional curriculum vitae. Some examples of courses are listed in Appendix 4.1.

Building Reflective Practice
To grow as educators, it is critical to reflect on what we are doing in the classroom, why we choose particular materials and methods, and whether our approach is working. Ideally, reflecting on our practice as educators is most helpful when it is approached systematically and a variety of information is used to better understand the extent to which our teaching actually is connected to learning. Of course, carefully analyzing how students perform on classroom assessments is an excellent place to start reflecting on how well our teaching materials and approaches are connected to student learning. There are many examples in the literature (see, e.g., Appendix 4.1) that provide advice on how to cultivate reflective practice. In the next few sections, several tools and approaches will be described that can be very useful for Fellows and Teachers in a GK–12 partnership.

Teaching Logs, Blogs, and Journals
Keeping a teaching log, blog, or journal is perhaps the easiest way to reflect on one’s teaching experiences.

University of Alaska Fairbanks GK-12 Fellow shows off the kit and curriculum he developed that uses bird features to demonstrate evolution principles.

In a journal, the Teacher describes how a particular teaching session or unit played out in the classroom. The Teacher can record how he or she felt during instruction. Furthermore, it is helpful to note how students reacted to and engaged in the unit, what elements worked well or did not work as planned, and what should be changed before the next class session or before the unit is used again.

Teaching logs can be kept on paper, or they can be web based (a blog). Several GK–12 projects have used digital teaching logs as a web-based project assessment tool. Teachers and Fellows sign on to a password-protected site and make entries about their experience with their curricular materials. They can be prompted as well to comment on how the team is functioning, thereby providing valuable information to project leaders about possible issues before they become real problems.

Peer Observations
Having a trusted colleague observe the teaching team in action can be a valuable way to improve teaching. The peer observer can note what the students are doing and how they are reacting in the moment of teaching. The observer also can comment on what strategies were particularly effective. Peer observations can be made in person during a class session or by viewing a video of the class session.
Peer observation works best when it is done systematically, with a checklist or a set of questions to answer during the observations (Appendix 4.5). It is important for the peer observer to meet with the GK–12 team before observing takes place, in order to understand what will happen during the class period. At the meeting, the members of the team also can alert the observer to any particular issues they anticipate during the session. After the observation period is over, the peer observer meets with the team to share what he or she has found and provide honest, constructive advice.

Like teaching logs and blogs, peer observations are a valuable assessment tool for documenting changes in the teaching approaches and skills of both GK–12 Teachers and Fellows. After meeting with the peer observer, the teaching team should reflect on how the observations align with their personal experience in the classroom and strategize on the kinds of changes that are feasible for improving the connection between their teaching and student learning.

Scientific Teaching
One especially effective way to improve the connection between teaching and learning is to envision our teaching as an experiment designed to have a positive impact on student learning. Using “scientific teaching,” an approach that mirrors scientific research (Handelsman et al. 2007), instructors review and revise their teaching in an iterative fashion based on evidence from assessment tools. To use a scientific teaching approach, it is critical to explicitly define what students should know and be able to do at the end of an instructional period and then to collect evidence to learn the extent to which the students have met the learning objectives. Evidence is composed of both quantitative and qualitative data (e.g., problem sets, objective questions, projects, observations of students in a lab setting, etc.). The key is that the assessment tools must be valid measures of student learning, behaviors, and attitudes that are closely linked to the learning outcomes defined for the unit or topic and the data are shared with the students so they know how well they are progressing. A scientific teaching approach allows instructors to make more informed decisions about the pace of instruction as well as teaching strategies that best link instruction with learning. In some GK–12 projects, graduate students have published the classroom research data they have collected in peer-reviewed journals (e.g., Whiteley et al. 2007 Piotrowski et al. 2007, Perkins and Brewer 2010).

PROJECT EVALUATION
Assessment, in a nutshell, is the practice of collecting data to better understand the extent to which project goals and objectives are being met. The resulting data can then be used to guide decision making about how to improve project implementation. (See Chapter 9 for guidance on conducting an evaluation of your project.) There are two kinds of programmatic assessment that may be valuable for

### Checklist of Considerations Regarding Scientific Teaching

- What knowledge and skills are relevant to the subject area?
- What should students know and be able to do at the end of the unit?
- What do proficiency and mastery look like in the subject area for this level in the curriculum?
- What evidence demonstrates that a student has achieved mastery and proficiency across the relevant content and skills previously identified?
- What evidence on learning would convince colleagues, parents of students, and other interested parties?

GK–12 projects, and these will be described next. Whichever kind is chosen, implementing it can be done internally within the project (by project staff) or externally (by an external consultant). Deciding on whether to do project assessment internally or externally will depend on the size and scope of a particular project and on the budget available for the assessment. In either case, many GK–12 projects have made examples of their assessment tools available through their websites; the examples can be excellent resources for developing an assessment plan that fits each particular project. Because educational assessment involves collecting data from human subjects, it is necessary to have the assessment plan, as well as the tools that will be used to collect data, reviewed by the Human Subjects Institutional Review Boards of both the university or college and the schools and school districts. There are likely to be special requirements for collecting assessment data from minors. It is essential that project staff and all of the graduate students and Teachers be clear about human subject data collection protocols before any assessment plan is implemented.

Formative Assessment

Formative assessment documents and reviews project activities and provides interim information for reviewing and redirecting the project as necessary. Often, formative assessment is shared with all participants as the project develops. A formative assessment plan will examine the effectiveness of recruitment activities, document the work of Teacher–Fellow teams as they create plans and research experiences for participating students, and review mentoring support materials and strategies. Typically, participating faculty, Fellows, project leaders, and staff are interviewed about the quality and effectiveness of project activities and are requested to make recommendations regarding additional project needs. Early on in a project, it is useful to gauge the perceptions of project leaders and staff, Teachers, Fellows, and district leaders to quickly identify any emerging issues or challenges. The development and implementation of courses, workshops, seminars, and informal social gatherings, as well as the overall reaction of participants related to these project activities, are reviewed. Sometimes, formative assessment for a GK–12 project might analyze the breadth of opportunities offered to K–12 students, the number of students involved in guided and authentic research experiences, and the barriers encountered in involving all students in research.

Needed improvements and project successes can be identified with a variety of tools, including surveys, questionnaires, focus-group discussions, individual interviews, and participants' reflective logs, to name just a few.

Summative Assessment

Summative assessment focuses on the overall quality and breadth of the project's accomplishments. Summative data include, for example, general demographic data on all participants; data on overall participation by Fellows and Teachers, and on their enthusiasm for future participation; the overall number of K–12 students participating in research experiences; information about the level of content and process mastery of students in GK–12 classrooms (e.g., results of pre- and post-tests, performance on standardized tests); and data on the degree to which Teachers' instructional practices have changed to reflect the “learning by doing” model and the level of inquiry-based instruction in and out of the classroom. Additional summative data might include the average time taken by Fellows to earn their degrees, the number and types of higher education placements after Fellows graduate, and the percentages of underrepresented groups among higher education participants and faculty.
EXEMPLARS

CONNECTIONS IN THE CLASSROOM: MOLECULES TO MUSCLES

University of Southern Mississippi GK–12 Project
http://www.usmgk12.org

The goal of the “Connections in the Classroom: Molecules to Muscles” (C2M2) is to enhance Fellows’ communication and teaching skills in an interdisciplinary research and education setting. Training Fellows begins in the spring prior to the Fellowship year when graduate students meet their Teacher partners. Training continues during the summer prior to entering the classroom. The Fellows participate in two important educational training activities. The first is a required course, taught through the College of Education, to introduce the Fellows to relevant ideas about pedagogy, lesson planning, and scientific inquiry. The second is a two-week intensive summer workshop spent with their partnering Teachers to provide each Fellow with a chance to learn about the particular needs of his or her Teacher’s classroom, to work with diverse students in schools that serve minorities, to discuss classroom liability issues, and to develop trust and working relationships through personality assessments and team-building exercises.

The training for Fellows continues during the school year. All of the Fellows are enrolled in a course that meets weekly to share research updates and further develop their educational expertise. Fellows work with staff in the speaking, writing, or learning center, as appropriate, to learn a variety of communication techniques that help them to interpret their research for funding agencies, legislative staff, and the general public. One technique used is to videotape the Fellow giving a presentation and then analyze the video for areas of possible improvement. In the spring, each Fellow is asked to give a formal presentation to a general university audience about his or her research.

The results extend beyond the project and high school setting. Project leader Sarah Morgan shares a story that illustrates success in developing improved communication skills. During three years of graduate school, one of the Fellows in the project had tried to explain his project to his mother, but to no avail. Following the first semester of training in the C2M2 Fellowship, he traveled home for the semester break. Using the new communication skills he developed as part of his GK–12 training, he was able to explain his research work to his mother for the first time. This example shows that not only do the Fellows learn to communicate with students and general scientific audiences, but they also learn to communicate the complexities of their research effectively to the general public.

ECOLOGISTS, EDUCATORS, AND SCHOOLS

University of Montana GK–12 Project
http://www.BioEd.org/ECOS

The Ecologists, Educators, and Schools (ECOS) project used the school yard and adjacent open areas nearby as outdoor laboratories for learning about science and the environment. The theme was “No Child Left Indoors.” Over the course of a year, ECOS Fellows and Teachers participated in a series of training opportunities to introduce participants to the project, teach content and methods of ecological science, develop innovative approaches to the teaching of science in K–12 classrooms, create teaching materials and resources, and develop a native garden at the school.
The ECOS Fellowship year began with a reception late in the spring semester for new GK-12 Fellows, their research advisors, and GK-12 Teachers from the partner schools. The reception provided an opportunity to describe the ECOS project to new participants and for the team members to meet. In early June, Fellows were brought together to prepare them for working with their partner Teachers, to learn about national and local science standards, and to begin strategizing on how they could link their research and disciplinary backgrounds to the standards.

Over the summer, Fellows and Teachers participated in two weeklong workshops. Teams engaged in an outdoor open-inquiry investigation in a local park (e.g., Feinsinger et al. 1997). Teams devised a researchable question, collected and analyzed data, created a simple poster describing their research and results, and presented their findings to the other ECOS teams. This experience was crucial and set the stage for the rest of the partnership year. During the workshop, teams identified an ecological theme for their work in the partnering school, established a planning calendar, determined equipment needs, and learned pedagogical approaches to outdoor ecological inquiry. Teams also focused on developing guided and open-ended inquiries, collaborated on an ECOS web-based natural history guide, and solidified plans for the school year.

Once the school year began, the Fellows met on a weekly basis with their school-based team and participated in a two-credit seminar course each semester. The course was designed to help them further develop their communication and pedagogical skills. Fellows also identified an area for a dissertation chapter related to their GK–12 experience, a requirement of the University of Montana GK–12 project.

Over the academic year, the ECOS project hosted three to four Institute days to bring the ECOS teams together, report on GK–12 activities at their schools, and learn one or two new approaches to using their school yards to teach ecology.

At the end of the academic year, the ECOS project hosted an annual three- to four-day writing retreat for Fellows in an off-campus residential setting to help them progress on their teaching dissertation chapters and to prepare manuscripts and reports on the successes and lessons learned as ECOS GK–12 Fellows for subsequent publication. By the end of the ECOS project, all of the Fellows had documented their ECOS teaching scholarship as one chapter of their dissertation and many of them had successfully published manuscripts, in collaboration with their partner Teachers, in teaching journals.

**FOR MORE INFORMATION**

- Bybee, R.W. 1997b. *Achieving scientific literacy: From purposes to practices.* Heinemann, Portsmouth, NH.
FOR MORE INFORMATION

- Novak, J.D. 1998. Learning, creating, and using knowledge: Concept maps as facultative tools in schools and corporations. Erlbaum, Mahwah, N.J.
CHAPTER 5
THE FELLOW–TEACHER PARTNERSHIP

Karen McNeal, Anna Stewart, Cynthia Brossman, Barbara Plonski, Cynthia Godoy, Tamara Battle and Tim Spuck

A biology Teacher and a GK-12 Fellow from Northern Arizona University work together at a summer institute.

CHAPTER HIGHLIGHTS

- Successful partnerships are based on shared goals, complementary strengths, and open communication and are essential for a successful GK–12 project.
- Fellows and Teachers collaborate through the distributed expertise model, i.e., Fellows bring scientific and technical expertise to the classroom while Teachers bring classroom management, teaching, and communication expertise.
- A strong and lasting partnership requires ongoing formative assessment of Fellows, Teachers, and students, as well as a collaborative backward planning process between Fellows and Teachers.
- Fellows often become role models for K–12 students and develop critical professional skills in mentorship, pedagogy, and communication.

AT THE CENTER OF ANY K–12 PARTNERSHIP with a university are Teachers and STEM GK–12 Fellows, each of whom brings diverse knowledge and expertise about science and science education to the table. But if a partnership is defined as a symbiotic relationship with mutual dependence and reciprocal benefits, what are the elements or strategies necessary to help ensure its success? Whenever two entities decide to join together, they will inevitably approach the relationship with different goals, values, or expectations; however, the key to a successful partnership is to understand each participant’s strengths, identify their needs, and develop strategies to help meet those needs. In a GK–12 partnership, Teachers provide experience in classroom management, communication, and pedagogy skills, while Fellows contribute cutting-edge research expertise. Through joint training and collaboration in K–12 classrooms, both learn to complement one another as, together, they lead students to a more thorough understanding of STEM curricula and scientific inquiry.

THE DISTRIBUTED EXPERTISE MODEL

Research indicates that a single individual cannot possess the wealth of knowledge required to address all aspects of complex learning environments adequately. By contrast, cognition is distributed among individuals and knowledge is socially constructed through collaborative efforts (Brown et al. 1993). This fact is most often demonstrated within the setting of the modern-day classroom. It has become well known in education theory that a student can reach a zone of proximal development (a target of the highest levels of comprehension and growth with assistance from others and/or powerful objects, such as technologies and models) (Vygotsky 1978). By engaging with others, a student internalizes what is learned in the group and continues to develop independently (Brown et al. 1993). This same principle can be applied to
professional collaborative working groups: ideas and tasks are shared by the group through contributions from distributed experts.

The GK–12 approach supports the notion of distributed expertise through students who work together in teams during inquiry-based practices while having access to expert science content contributions through the Fellow–Teacher partnership. These interactions develop into a mutually beneficial relationship in which both parties combine their expertise to accomplish a similar classroom learning goal, as shown in Table 5.1 (Bledsoe et al. 2004). Here, the STEM GK–12 Fellow takes on the role of the professional scientist, providing support in both STEM content and the authentic STEM process. Together, the Fellow and Teacher develop innovative lesson plans that integrate current research with curriculum standards. Fellows provide support to students by serving as role models, mentors, and content experts, as well as by sharing their experiences, including graduate student life, tips on how to succeed as an undergraduate, and opportunities to conduct research. Fellows also provide support to Teachers and students by sharing knowledge of their network of scientists from the university to professionals from the community.

The Teacher is the pedagogical expert who, in a sense, is the expert “orchestra conductor” for the classroom. The teacher knows how to communicate complex ideas to K–12 students and members of the general public, as well as how to create and maintain a well-managed classroom that is a safe and inclusive learning environment for the students. Although dialogue about classroom activities and practices must take place on a regular basis between Fellow and Teacher, the Teacher is ultimately held accountable for what is learned and, therefore, must

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### KEYS FOR SUCCESS: IDENTIFYING AND FACILITATING GOOD FELLOW-TEACHER PARTNERSHIPS

- Help clarify the roles of Teachers and Fellows in the classroom.
- Have the Fellow and Teacher identify and communicate their perceptions of their own role and the expectations they have of their partner. They should be flexible about sharing leadership in the classroom, depending on the situation.
- Help Fellows and Teachers to understand that Fellows provide STEM content—they are not student teachers or just an extra set of hands. Fellows must respect the Teachers’ authority in the classroom, just as Teachers must respect the Fellows’ STEM knowledge.
- Set up predetermined times for the partners to give each other feedback. Since the Teacher is the expert in pedagogy, it is his or her role to guide the Fellow toward effective methods of teaching and classroom management. Likewise, Fellows should provide STEM content feedback to Teachers during curriculum development.
- Ensure that regular planning meetings take place between Fellow and Teacher.
- Identify ways to coordinate logistics—plan meetings, use email or phone to convey information, meet out of class, and share information electronically about upcoming lessons that both Teachers and Fellows can edit online.
- Find connections between the Fellows’ research and the K-12 curriculum standards. Teachers can visit the Fellows’ labs to learn about the kinds of research they are conducting. Conversely, Fellows should learn about the curriculum standards to which Teachers and their students are held accountable.
- Provide clear guidance on how the Fellow and Teacher should handle problems that may arise between them or with others on the project. Who is the go-to person if a problem arises?
- Create regular opportunities for all Fellows and all Teachers to meet and discuss successes and challenges they have faced.
be responsible for all final decisions regarding what, when, and how concepts should best be taught in the classroom. The distributed expertise approach also includes the contributions of students in the classroom setting. Students bring their own unique expertise to the classroom, such as expertise in social media or computer-related activities, both of which can be useful in various learning environments.

Fellows described their roles in the classroom:

“I believe that the students view me as the fun lady who takes them to lab. They know that I am there to make learning fun. Since I’m not grading their papers or disciplining them, they are open with questions and opinions about what we are doing.”

“I am in the classroom as the ‘scientist,’ not as a student Teacher or disciplinarian. Because of this role, I feel at times I have less power to control the classroom when they are unfocused and obstinate, but more power at times when talking about science and the neat things that can be learned from the field.”

Teachers described their roles in the classroom:

“I have many roles in the classroom, [including] being a facilitator, a manager, an assistant, [and] a mentor, as well as a student. These roles occur as various times while [I am] working with the students and the Fellows.”

“I am always on call as the supervisor for disciplinary purposes. Sometimes I do direct instruction with support from the Fellows. Sometimes I am the support as Fellows provide instruction. During inquiry, I am the floater: [doing] whatever and [being] wherever I am needed most.”

The distributed expertise approach is important in the GK–12 project because all parties benefit from this exchange of information and have the capability to continually reach their zone of proximal development. The students in the classroom learn from their peers, the Teacher, and the Fellow who fills the role as the new resident science expert. The Teacher learns current research trends and ideas in the content domain from the Fellow; receives current technology, laboratory, field, and/or research skills from the Fellow; and has more time for reflection and revision while collaborating with the Fellow in the delivery of STEM instruction. The Fellow is provided the opportunity to learn how to communicate science to nonscientists, has a teaching mentor who will help improve the Fellow’s own teaching skills, and develops skills in curriculum development and classroom management through regular exchanges with the Teacher. For many graduate students, this is first time they assume the role of “the expert,” a role that can empower them and build professional confidence as well.

Defining Roles in the K–12 classroom

The distributed expertise approach is also important to consider as regards role development in partnerships, such as those between the Fellow and Teacher. Such role development is needed in GK–12 classroom projects. Role development with clear definitions between Teacher and Fellow is important in creating a vibrant and productive partnership. Poorly defined roles can leave partnerships and role dynamics to develop idiosyncratically, invite confusion, and lead to potential conflict that may create barriers to success (Nelson 2002; Thompson et al. 2002). As a result, project planners should have clear expectations for participation at the outset and should clarify roles as early in the collaboration as possible. Supervision of participants, and open communication between participants and planners, throughout the implementation of the project are also vital to ensuring success.

Each GK–12 project is unique in its definition of Fellow–Teacher roles; however, the most successful classrooms were those in which both the Teacher and the Fellow were dynamic and leadership roles were
distributed in accordance with the learning goals and the classroom situation. For instance, the Fellow may conduct a lesson in the classroom with assistance from the Teacher, and vice versa when content dictates that the Teacher should take the lead. Over time, the partnership will mature into a seamless co-teaching relationship. In addition, Fellows may have co-taught with one another in pairs or groups and brought aspects of their different STEM content areas into the classroom lesson(s). The distributed expertise model allows for leadership to be shared in the classroom and accounts for the knowledge each individual brings to the particular learning situation, in which the leadership role may be flexible depending on the needs of the lesson.

FOUNDATIONS OF FELLOW–TEACHER PARTNERSHIPS

Every Teacher–Fellow partnership will have its own idiosyncratic qualities, but all successful partnerships depend on at least three foundational components: shared goals, complementary strengths, and open communication.

Shared Goals

Fellow–Teacher pairs should engage in a discussion about the common goals of their partnership. Through this dialogue, both partners will feel a sense of ownership and more readily embrace their roles in the success of the project. A clearly defined mission unites both the Fellow and the Teacher in a common purpose.

With most GK–12 projects, the objectives and anticipated outcomes can be generalized (Usselman et al. 2005). GK–12 Fellows seek training in educational pedagogy, gain teaching experience, and learn from direct interaction with experienced Teachers. Fellows anticipate improving their teaching, communication, and leadership skills, as well as increasing their understanding of the K–12 culture and diversity. GK–12 Teachers aim to enhance their STEM content and educational technology content and find inspiration for new curricula. Teachers can expect to gain a greater understanding of science, the scientific process, and engineering, and make personal contact with local scientists. K–12 students will benefit from improved science teaching by Teachers and new mentors, as well as make contact with practicing scientists.

Ultimately, the goal of spurring students’ interest in science and increasing their understanding of STEM content is paramount to all parties involved. Although these goals can be generalized to all GK–12 projects, particular projects may have specific goals customized to their communities. In any case, a clear understanding of the goals and expectations of the GK–12 project is critical to its success.

Complementary Strengths

It is important to recognize strengths that each partner brings to the relationship, and determine how best to leverage these strengths. As discussed in the first section of this chapter, Teachers and Fellows each bring a specialized expertise to the partnership. The manner in which this distributed expertise is shared between them is critical to maintaining a successful Fellow–Teacher partnerships. Project directors and project managers can help clarify the roles of Teachers and Fellows in the classroom.

In a study of how GK–12 partnerships work, the following questions were asked (Nelson 2002): “How are pedagogical decision made?” “How do partners
respond to an observed classroom event?” and “How does one partner respond to ideas offered by the other?” In order to answer these questions, Nelson observed 10 Fellow–Teacher pairs over the course of a year and, on the basis of her observations, identified three types of interactions: knowledge negotiation, knowledge consultation, and knowledge rejection.

In knowledge negotiation, Fellows and Teachers questioned each other's ideas with the intention of understanding each other. They tended to build on each other's knowledge, examining alternative perspectives and approaches. They interacted frequently, either in co-planning or in co-teaching lessons. In knowledge consultation, each person maintained his or her own area of expertise and shared it when appropriate or needed. Most partnerships broadly fell into this category, in which interactions were characterized by sharing knowledge to meet a specific need, rather than by inquiry. In knowledge rejection, one person listens to the other's ideas, but ultimately rejects them. This type of interaction is characterized by Teachers who are resistant to externally imposed ideas or by partners who view the other's ideas as irrelevant, impractical, or erroneous.

Nelson observed that power was based on status and control, and was a significant element in how partnerships developed over time. Since it is widely held that scientific knowledge receives higher status than Teacher knowledge, each partner must be sensitive to issues of perceived hierarchy and work proactively to level the playing field by practicing knowledge negotiation. She concludes that, in order to build partnerships based on knowledge negotiation, projects should provide a forum for Teachers and Fellows to engage jointly in explorations of teaching and learning science, together building relationships based on dialogue and inquiry. Whether through summer workshops or after-school sessions, these forums can help build a spirit of participation, and they have the greatest potential for transforming the resources of each partner and providing effective professional development for Teachers during which they are challenged to think differently about their practice.

Open Communication
In order to establish open communication, trust, and teamwork, many projects conduct team-building exercises as part of their training in advance of classroom activities, usually in the summer. Some examples include rope courses, team challenges, and improvisation. Northwestern University took advantage of its theater department to introduce Fellow–Teacher teams to improvisation skills. In addition to building a sense of camaraderie, these skills help both Teachers and Fellows respond to student questions and teach them to recognize the nonverbal feedback they receive from the students. These types of activities provide opportunities for participants to become more comfortable working with one another. In some cases, Teachers and Fellows complete a contract with one another, specifying the amount of time the Fellow will spend in the classroom, the role of each partner in the classroom, school rules by which the Fellow will abide, responsibilities of the Teacher, the manner in which they will give each other feedback, and more. By putting expectations for each other in writing, partners must think about their collaboration in advance. Not all partnerships require contracts to set responsibilities, but all partnerships require mutual understanding of each partner's duties.

See Appendix 5.1 for a discussion of common pitfalls and successful strategies for Fellow–Teacher partnerships.

FORMATIVE ASSESSMENT OF FELLOWS AND TEACHERS: FEEDBACK TO STRENGTHEN THE PARTNERSHIP
Ongoing formative assessment is a necessary component of a successful classroom partnership between Fellows and Teachers, because assessment helps both parties develop more effective teaching and communication techniques. Ongoing assessment is especially important for those Fellows who have little prior teaching experience in the K–12 classroom. It is also important for the Teacher who may be co-teaching new and unfamiliar STEM subject content and research skills.

For feedback to be effective, Fellows and Teachers have to build a relationship grounded in open communication and where regular feedback is
expected and welcomed. Teachers and Fellows can assess each other’s performance through regular informal feedback via emails and weekly meetings to review what worked and what didn’t work in the lessons of the previous week. They can then use the results of the classroom assessments (Table 5.2) as the basis for a conversation on how to improve student learning in upcoming classes. Teachers and Fellows can also provide each other with formal feedback, such as oral or written quarterly reviews of each other and the use of rubrics for specific lessons. For example, a Teacher could use a rubric to assess a lesson presented by the Fellow and vice versa. Fellows and a Teacher describe how they give their partners continuous formative feedback:

“My Teacher and I discuss successful and unsuccessful teaching tactics between classes so that each succeeding lecture is better and better. We also discuss the possible pitfalls in upcoming lessons so that presentations can be the most effective. We evaluate these points both inside and outside of the classroom.”

“Feedback is immediate and direct. We have lunch together and we spend time between classes discussing and brainstorming the next activity. Everything is a work in progress.”

“I try to jot down notes as [the Fellows] teach to highlight success and identify and modify what could be improved. We are always honest and open with any concerns we might have.”

Fellows and Teachers can also seek feedback from their peers, from university faculty and project managers, and from school administrators. Fellows can give each other feedback by visiting each other’s classroom and conducting formal or informal observations. They could use a specific assessment guide or rubric, or they could take more general notes and meet together afterward to discuss what worked well and what could be improved. Peer assessments teach Fellows how to give and receive feedback, a critical skill for these future mentors and Teachers. Fellows can also empathize with each other about the challenges of the K–12 classroom setting and can share tips about what worked for them in their classrooms. Weekly meetings with project directors, project managers, and other Fellows are another important source of formative feedback for the Fellow. During the meeting, Fellows can share their recent challenges and successes in the classroom and receive advice from their peers and supervisors. Teachers can also receive formative feedback from project managers, project directors, and K–12 administrators through formal and informal formative evaluation techniques, such as classroom observations and focus groups with K–12 students.

**Table 5.2 Examples of Formative and Summative Assessments**

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MENTORING K–12 STUDENTS
A successful Fellow–Teacher partnership facilitates productive interactions between Fellows and students. The Teacher is often the bridge between Fellows and students to foster the mentor–mentee partnership. Role models can have a significant influence on early career choices and the academic performance of younger students (Adya and Kaiser 2005, Zirkel 2002, Buck et al. 2008). As the expert scientists in the classroom, GK–12 Fellows have the opportunity to become role models and near-peer mentors of K–12 students, can positively influence students’ perceptions of STEM disciplines, and can pique their interest in entering STEM fields (Aschbacher et al. 2010, Thompson and Lyons 2008). Teachers who collaborated with Fellows described the impact of the Fellows on the students:

“Interacting with real scientists allows students to see the possibility for them to be scientists one day.”

“Students definitely see scientists in a different light.... They realize [that the Fellows] can be approached as real people who happen to have a passion for learning and sharing knowledge and research. They also have lost their fear of science. They are more open to new ideas and more comfortable asking questions.”

Fellows can act as role models and mentors for students by sharing their professional experiences with the students, by talking about their career and educational path, and by sharing their research experience.
in the classroom. They can develop a mentoring relationship through one-on-one tutoring of students or by meeting with students after school to help them develop their ideas for a long-term research project. Fellows can also act as mentors by hosting students for a day at their university to show them their laboratory or by engaging them in research activities on campus.

Many graduate students go on to teach and mentor at universities and in other settings and yet receive little formal training in teaching or mentoring. The GK–12 approach is an effective way for graduate students to develop critical interpersonal skills such as setting professional boundaries in the Teacher–student relationship, listening and responding to students’ concerns, resolving disputes, providing encouragement and guidance, and offering career counseling (Fischer and Zigmond 1998, Trautmann and Krasny 2006, Tanner and Allen 2006).

Fellows share their experiences as mentors:

“If you make an effort to get to know the students individually, they will respect you, and this enables you to expose them to bigger and better learning opportunities.”

“From this experience, I have learned compassion. Compassion is something that comes from learning about the students, listening to them talk about their families and what they love, and knowing them. It is a great thing...to expose them to math and science they would not normally see until later, helping them gain an understanding for subjects which [I am] so passionate about, and seeing [them] get excited when it clicks for them.”

Although some Fellows may find it difficult to connect and communicate with their students initially, these skills are developed through practice, and K–12 Teachers and university faculty can play a critical role in helping the Fellow to navigate the mentoring relationship. Ultimately, many Fellows find that they are able to connect with students as near-peer mentors, since the Fellows are often young and still students themselves.

KEYS FOR SUCCESS: PRINCIPLES OF GOOD FEEDBACK PRACTICE

- Clarify the standards of good performance by setting goals, criteria, and expected standards.
- Facilitate the development of self-assessment in learning.
- Encourage Teacher and Fellow dialogue around learning.
- Encourage positive motivational beliefs and self-esteem.
- Provide opportunities to close the gap between current and desired performance.
- Provide Teachers and Fellows with information that can be used to help shape their teaching.

SOURCE: NICOL AND MACFARLANE-DICK 2006

“The students are very friendly with the Fellows because they are younger than me. After the first lessons presented by the Fellows, the students come to expect really 'cool' things to happen in class when the Fellows are teaching. The students also begin to ask more science-related questions.”

–GK–12 Teacher
The IMPACT LA GK–12 project hosts a two-day engineering and science summer camp for neighboring middle school students. Fellows and GK–12 Teachers lead science and engineering labs and activities to spark students’ curiosity in STEM fields. The summer camp is also a catalyst to begin the Fellow–Teacher working relationship and to define their roles in the distributed expertise model. In the weeks prior to the camp, the Teacher and Fellow begin to develop and refine the activities for the students. The Fellows employ their STEM content and technological expertise by designing activities that relate to their own research. With the help of the Teacher, the Fellow begins to understand how to conduct classroom management and how to focus students’ attention on the planned activity. During this time, the Fellow learns how to speak in front of students and how to give instructions and information that a middle school student will understand. Teachers also have the opportunity to model good classroom management strategies when they co-teach the lab or activity with the Fellows. This unique inquiry-based learning experience allows the Fellow to understand how important his or her role is in the classroom and how the Fellow can influence and excite students in the STEM fields. One week after the 2011 summer camp, IMPACT LA received a letter from a parent:

“My son was definitely inspired. He was looking forward to returning on the second day, and before bedtime on that Friday, he said he wanted to be an engineer, ‘just like the blond Teacher’.... My daughter showed an interest in the DNA and biology activities, which is more than I could have hoped for....Your two-day project has done more to inspire my children than months of attending the other average, run-of-the-mill summer projects.”
THE GK–12 APPROACH aims to develop scientists who are effective communicators, K–12 Teachers who have a rich content knowledge in STEM, and K–12 students who are scientifically literate. One of the main ways that these goals are met is by integrating GK–12 Fellows’ research into the classroom. Fellows enter the classroom as resident science “experts” who offer their research skills, knowledge, and know-how by collaborating with GK–12 Teachers and interacting with students. Fellows bring scientific authenticity to the classroom through many approaches, including (1) utilizing skills and knowledge from their STEM discipline in classroom instruction, (2) supporting student-led research projects, (3) developing lesson plans that capture key concepts, protocols, or procedures from their research, (4) bringing students to the field to visit local research sites, and (5) convening or judging science fairs or other venues at which students can share their research findings. In addition, Fellows serve as near-peer mentors and role models to K–12 students, showing them that scientists are “real people” who are part of a scientific community that pursues knowledge through scientific research. This chapter will emphasize how GK–12 Fellows and Teachers bring STEM content and research to the school setting to meet the goals of integrating research and education.

PRINCIPLES OF AUTHENTIC SCIENTIFIC INQUIRY
A core goal of GK–12 projects is to engage students in authentic scientific inquiry in order to teach skills in problem solving and critical thinking that are necessary for a scientifically literate citizenry. GK–12 Fellows and Teachers bring authentic science to the classroom by engaging students in inquiry, which can be defined as the “diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work” (National...
The often cited 5E model illustrates the steps in the basic inquiry learning cycle: Engage, Explore, Explain, Elaborate, and Evaluate (BSCS and IBM 1989) (Figure 6.1). When students are engaged in inquiry, they learn to ask and refine questions (Engage), design and conduct investigations (Explore), gather and analyze data (Explore/Explain), make interpretations and report findings (Explain), and make conclusions and ask new questions (Elaborate) and assess understanding (Evaluate) (Colburn 2000, Krajcik et al. 2000). Teachers and Fellows should consider the detailed steps illustrated in Table 6.1 when designing inquiry experiences for the classroom (Etheridge and Rudnitsky 2003), keeping in mind that inquiry can take many forms, ranging from confirmation to open inquiry (Banchi and Bell 2008, MWM 2009) (Table 6.2).

**“Inquiry is something that students do, not something that is done to them.”**  
—Center for Science, Mathematics, and Engineering Education 2000

Authentic scientific inquiry in the classroom is a collaborative problem-solving process that involves teachers, students, and scientists working together to explore a specific research question or problem (Brown et al. 1989, Edelson et al. 1999, Hart and Nolan 1999). As described previously, in the distributed expertise model GK–12 Fellows play a key role in bringing authentic science to the classroom by acting as resident science experts. The inquiry-based approach is an effective vehicle for Fellows to translate their research into classroom activities. As the pedagogical experts in the classroom, GK–12 Teachers play a key role in ensuring that the Fellows’ scientific expertise is effectively translated into student learning of appropriate STEM content and research skills. Inquiry-based experiences may also involve parents, other teachers, other Fellows, school administrators, and university faculty in the classroom to participate in student research projects and classroom lessons or as guest lecturers.

The inquiry-based approach has been successfully adopted by many GK–12 Fellows and Teachers because it is flexible and adaptable to a variety of projects. There is no one-size-fits-all inquiry-based approach. Inquiry-based experiences can range from a single class period to a semester or yearlong research experience and can be broadly applied to STEM subject areas and research fields. Inquiry-based experiences can be enriched through the use of many other innovative teaching strategies, including technology-supported learning, hands-on approaches, model-based learning, collaborative teams, and in-class real-world applications. As described later in this chapter, technology is an especially effective and important means of enriching inquiry-based learning, and Fellows can

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Figure 6.1 The 5E Inquiry Learning Cycle Model

SOURCE: BSCS AND IBM 1989

Teachers play a key role in ensuring that the Fellows’ scientific expertise is effectively translated into student learning of appropriate STEM content and research skills. Inquiry-based experiences may also involve parents, other teachers, other Fellows, school administrators, and university faculty in the classroom to participate in student research projects and classroom lessons or as guest lecturers. The inquiry-based approach has been successfully adopted by many GK–12 Fellows and Teachers because it is flexible and adaptable to a variety of projects. There is no one-size-fits-all inquiry-based approach. Inquiry-based experiences can range from a single class period to a semester or yearlong research experience and can be broadly applied to STEM subject areas and research fields. Inquiry-based experiences can be enriched through the use of many other innovative teaching strategies, including technology-supported learning, hands-on approaches, model-based learning, collaborative teams, and in-class real-world applications. As described later in this chapter, technology is an especially effective and important means of enriching inquiry-based learning, and Fellows can

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A Texas Tech University 2nd-year GK-12 Fellow (center) leads several new GK-12 Fellows and their partner-Teachers through a module on the wave nature of light and electrons.
play a key role in bringing technology resources from the university to the classroom.

The benefits of authentic scientific inquiry are that students can become active lifelong learners by acquiring scientific knowledge in a meaningful context and learning how to explore their own ideas about how the world works (Brown et al. 1989, Goldman and Petrosino 1999, Edelson et al. 1999, Hart and Nolan 1999). Authentic scientific inquiry also helps students to build self-esteem by allowing them to take an active role in their learning process while reinforcing their physical, emotional, and cognitive skills. Since this approach is sensitive to the backgrounds, interests, and needs of students, it can be appropriately utilized in a variety of contexts and settings, including rural, urban, and suburban locales; culturally diverse populations; at-risk students; and a range of grade and performance levels (Eisenhart 2001, Barton 1998, Warren and Rosebery 1995).

There are times when inquiry is not the preferred teaching method and it is more effective to teach didactically, through reading tasks, or via other direct teaching mechanisms (Table 6.3). One disadvantage of using inquiry-based learning is that it may require more class time to conduct an activity. It may also require more planning, preparation, and responsiveness from the Fellows and Teachers, who have to develop facilitation skills to help students to ask good questions and think independently. The teaching method employed is ultimately at the discretion of the classroom Teacher.

In the sections that follow, we will take the reader through examples of how to use inquiry-based experiences and other teaching strategies to integrate STEM content and research into K–12 classrooms in a variety of settings. We will offer tips for implementation and present exemplars that demonstrate the teaching and learning goals of a GK–12 project.

### Table 6.1. Stages of the Inquiry Cycle

<table>
<thead>
<tr>
<th>5E Model</th>
<th>Inquiry Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluate</td>
<td>1) Take into consideration students' backgrounds and interests</td>
<td>Use probing questions and formative evaluation tools to assess: What sort of knowledge do learners have? What are their misconceptions? What are their interests?</td>
</tr>
<tr>
<td>Engage</td>
<td>2) Create and describe a system of variables</td>
<td>Variables may be specified by the Fellow or Teacher, or the students may choose them.</td>
</tr>
<tr>
<td>Engage</td>
<td>3) Design an immersion experience</td>
<td>Experiences could include a demonstration, a video, or a physical model that is explored in the classroom to stimulate the students’ curiosity of the system and thus motivate them to continue to the research phase.</td>
</tr>
<tr>
<td>Explore/Evaluate</td>
<td>4) Generate researchable questions</td>
<td>Questions may be developed either by the students in small groups or by the whole class.</td>
</tr>
<tr>
<td>Explore/Evaluate</td>
<td>5) Conduct the research</td>
<td>Students investigate the research questions either in collaborative groups or as individuals. Students may be assigned to groups, and each group may pursue similar or different research questions depending on the structure of the activity.</td>
</tr>
<tr>
<td>Explain/Elaborate/Evaluate</td>
<td>6) Design a consequential task</td>
<td>Provide students with the opportunity to demonstrate what they learned. Consequential tasks could include offering the class a group presentation, making a poster, creating a model system to complete some design requirement, or writing a report.</td>
</tr>
<tr>
<td>Elaborate/Evaluate</td>
<td>7) Assess understanding</td>
<td>Formative and summative assessments allow Fellows and Teachers to determine what the students have learned in the activity, to identify follow-up activities in order to address any knowledge gaps and misconceptions, and to build additional complexity.</td>
</tr>
</tbody>
</table>

### Table 6.2 Levels of Inquiry

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confirmation</td>
<td>Traditional &quot;cookbook&quot; labs: Students follow a prescribed procedure to confirm a scientific principle. The expected results are known in advance.</td>
</tr>
<tr>
<td>Structured</td>
<td>No predetermined answer: Students investigate a question presented by the Teacher through a prescribed procedure, but their conclusions are based on their own investigation.</td>
</tr>
<tr>
<td>Guided</td>
<td>No predetermined method: Using research methods that they develop, students investigate a question presented by the Teacher.</td>
</tr>
<tr>
<td>Open</td>
<td>No predetermined question: Students investigate questions that they formulate and test through research methods that they design.</td>
</tr>
</tbody>
</table>

STRATEGIES FOR INTEGRATING RESEARCH INTO THE CLASSROOM

There are many strategies that GK–12 Fellows and Teachers can employ to bring STEM content and research into the classroom (Table 6.3). Following are several examples that illustrate some of these approaches by drawing on successful GK–12 projects.

Setting the Stage

The proper introduction of the GK–12 Fellow to a new class of students is an important part of setting the stage for research in the classroom. The Teacher should introduce the Fellow as a professional scientist, engineer, or mathematician and should explain that the role of the Fellow is to help the students to learn STEM concepts and skills, to expose them to STEM disciplines and career opportunities, and to enrich and expand STEM concepts related to the Fellow's research. The Teacher should clarify that the role of the Fellow is different from that of a student teacher or teacher's aide. An effective strategy that has worked for many GK–12 Teachers is to present the Fellow as someone who will bring engaging activities to the classroom. The Fellow can then introduce him- or herself and capture the attention of the students by showing a PowerPoint presentation or broadcasting a podcast that tells the story of the personal experiences that have shaped the Fellow's career. Sharing these experiences will help students to relate to the Fellow and set the foundation for the mentoring relationship between student and Fellow.

Bringing GK–12 Fellows’ Research into the Classroom

Fellows can bring research into the classroom in ways that are synergistic with their research efforts outside the classroom. For example, Fellows can have students collect data or build datasets that contribute to the Fellow's graduate research or other citizen science projects.

Fellows can also develop lessons that direct students to investigate research questions germane to the Fellow's own research. Alternatively, Fellows can provide students with experiences that enable them to sharpen their technical skills and acquire content knowledge about a particular theme that aligns with the Fellow’s research. One Fellow described the impact of bringing his research to the classroom in this way:

“I had a handful of students who were so intrigued with an acid/base/pH lesson that I presented that they came up on their own with a set of science fair projects on pH.... This stemmed from my research on Australian pine, where I collected soil and looked at the soil properties (including pH) to see how Australian pine modified the environment.”

Technology to Bring Laboratory and Field Experiences to the Classroom

Inquiry-based experiences that utilize technology and physical models have been shown to be especially effective in the K–12 classroom (Edelson et al. 1999, McNeal et al. 2010, Miller et al. 2010, Sell et al. 2006). GK–12 Fellows and Teachers can engage students in scientific inquiry by integrating common classroom technologies, such as smart boards, computers, clicker systems, and calculators, with resources available from their university, including library databases, STEM software tools, web-based curriculum, and other technologies. Fellows can use technology to bring their laboratory or field research into the classroom through multimedia presentations, demonstrations, and student simulations of Fellows’ research methods, among other strategies. This approach is especially relevant, given the expanding technological knowledge that students need to be scientifically literate citizens and the rapid technological advances in STEM fields today.

Student-directed Research Projects

GK–12 Fellows can bring scientific inquiry to the
“Students love technology and... are naturally good at using it. When given the opportunity to take the learning experience in their own hands and out of the textbooks, they... become limitless. They will often take the intended lesson and apply the math or science to another topic. The inquiry, the implementation of my research, and incorporating technology into the lessons are what engage the students. Once they are engaged, the learning experience becomes effortless....”

—GK–12 Fellow

classroom by guiding students in developing long-term independent research projects that last anywhere from several weeks to a full year. (See the exemplar from the State University of New York College of Environmental Science and Forestry [SUNY-ESF].) This approach may be more appropriate with older or more advanced students, but can be modified to accommodate younger students. For example, high school students could conduct their research independently or in small groups, whereas a class of elementary school students could all work together on a research project that is specified by the Teacher. Long-term research projects can span a range of inquiry, with more advanced students conducting research through open inquiry and beginner students conducting research through structured or guided inquiry (Table 6.2).

To develop their research project, students follow the general steps of the inquiry process, from identifying research questions and hypotheses to gathering, analyzing, interpreting, and presenting their data (Stewart et al. 2009). There are many different methods that students can use to conduct research, and the appropriate method depends on the students’ research interests, the grade level, access to resources, and feasibility. Students can investigate their research question by conducting primary research, in which they collect and analyze new data from the field or laboratory. Students can also investigate their research question by analyzing and interpreting data that were previously collected by an outside source (secondary data), such as data from online databases, geographical information systems (GIS), publications, or experts. The final product of the long-term research project allows students to synthesize and communicate their research findings. Students can present their research through a PowerPoint presentation, a scientific paper, a poster, or other formats appropriate for their grade level. This presentation could be limited to the Teacher(s) and peers. However, presentations to university faculty and graduate students or a presentation at a professional STEM meeting can be much more rewarding for K–12 students.

A long-term project provides students with the opportunity to receive repeated feedback over an extended time, allowing them to grow and gain confidence in their ability to communicate their research. Having students keep a research binder in which they store all assignments related to the project is an effective way for students to track their own growth over the course of the project. Students are often amazed to see their intellectual progress, from initial brainstorms and research proposals at the beginning of the year to their final research report in June.

Table 6.3 Methods for Bringing Research to the Classroom

<table>
<thead>
<tr>
<th>Teaching Opportunity/Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Didactic teaching/lecture</td>
<td>Fellow directly teaches STEM concepts, using lecture-style approaches (e.g., PowerPoint)</td>
</tr>
<tr>
<td>Inquiry-based learning</td>
<td>Fellow provides students opportunities to engage in authentic research through inquiry-based practices and steps. The opportunities could range from one class period to a yearlong activity in the classroom.</td>
</tr>
<tr>
<td>Hands-on activities</td>
<td>Fellow provides students with hands-on experiences, using laboratory materials, models, equipment, etc.</td>
</tr>
<tr>
<td>Demonstrations/videos/media</td>
<td>Fellow provides classroom demonstrations or other engaging media to provide context, curiosity, and explanation to a given topic.</td>
</tr>
<tr>
<td>Technology-supported learning</td>
<td>Fellow provides access to technologies such as computers, software, or equipment to support learning.</td>
</tr>
<tr>
<td>Games and competitions</td>
<td>Fellow creates opportunities for students to compete in games in order to learn or review a given topic. This method may be especially helpful for unit reviews.</td>
</tr>
<tr>
<td>In-class tutoring and group assistance</td>
<td>Fellow provides individual students and groups with assistance with homework or class work.</td>
</tr>
</tbody>
</table>
For example, GK–12 Fellows from SUNY–ESF worked with high school students to help them develop independent yearlong research projects, including the following:

- Comparing the average ecological footprint of people from urban and rural areas by surveying other students’ and Teachers’ urban and rural high schools.
- Setting up a system in the high school cafeteria to gather food waste. Students analyzed the composition and volume of food waste for the entire school and then developed and implemented a composting system.
- Exploring the effect of climate change on plant growth by studying the effect of different climate conditions (drier, wetter, hotter, cooler) on the growth of grass over several months in the classroom.
- Assessing the role of fertilizer use on grain production in the United States over the last 50 years by gathering data from online databases and conducting a basic statistical analysis to evaluate the association between the two variables.

GK–12 Fellows can guide students through each step of the research process by presenting a series of lessons on topics such as how to develop research questions and hypotheses, different ways to collect data, how to interpret data by using basic math and/or statistics, and how to write a research report. Fellows can integrate examples from their own research into these lessons—for instance, by sharing a copy of a simple research or grant proposal when they teach the lesson on how to develop research questions. Fellows and Teachers should meet with students one-on-one to help them identify their research topic and refine their research questions. Fellows can also support and mentor students by putting them in contact with local experts and professional organizations relevant to the students’ research.

By guiding students through long-term research projects, Fellows and Teachers can effectively teach STEM content and skills in analysis and.
communication. A student described his experience with research:

“The research project allowed us to engage in hands-on work while also gaining valuable information from the readings, and learning both to read and write like a scientist.”

See appendix 6.1 for additional examples of integrating research in the classroom.

**STEM Current Events and Careers**
In addition to sharing research skills and techniques from different STEM fields, Fellows can integrate STEM content into the classroom by leading discussions about current STEM events, new scientific discoveries, and career opportunities. Fellows can also bring in guest speakers from the university and the community to talk about their personal experiences in different careers. Fellow can showcase a STEM “career of the week.” For instance, in the INSPIRE project at Mississippi State University, Fellows created videos of careers in their STEM disciplines that showed them in their laboratories, in their workspaces, and at research centers, to illustrate what someone in their field may study and how their research was applied in the real world. The videos also displayed statistics related to career options in their field and the type of education needed for each career sector. In addition, Fellows can expose students to scientific practices to show the students how scientists work in the real world. For example, Fellows can share their experience attending a STEM-related conference by bringing in a poster that they presented there. All of these practices will encourage students to participate in science fairs and workshops, and may spur students to consider a career in a STEM discipline.

**PLANNING EFFECTIVE LESSONS**
The rubber hits the road when GK–12 Fellows and Teachers collaborate to plan and carry out lessons that integrate STEM content and research into the classroom. The process begins by analyzing data from various forms of student output (e.g., exams) and then using content standards, curriculum frameworks, and instructional materials to develop lessons. The Teacher’s expertise in pedagogy gives him or her the responsibility for guiding the lesson-planning process, especially at the beginning of the year, when the Fellow is new to the classroom. In most cases, this process focuses on developing lessons that will help students meet state standards for specific content areas and grade levels. Each state determines the standards that must be taught and, ideally, achieved by the student. Teachers use these standards as the

<table>
<thead>
<tr>
<th>Step</th>
<th>Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify learning goals</td>
<td>What do you want students to know?</td>
</tr>
<tr>
<td></td>
<td>What do you want students to be able to do?</td>
</tr>
<tr>
<td></td>
<td>Why is this difficult for them to know or do on their own?</td>
</tr>
<tr>
<td>Determine acceptable evidence</td>
<td>How will you know that they got the point of the lesson?</td>
</tr>
<tr>
<td></td>
<td>How will you assess that they got it?</td>
</tr>
<tr>
<td></td>
<td>What counts as understanding in your class?</td>
</tr>
<tr>
<td>Plan learning activities and instruction</td>
<td>What activities will you use to make sure that they got the point of the lesson?</td>
</tr>
<tr>
<td></td>
<td>How are these activities connected to students’ understanding?</td>
</tr>
</tbody>
</table>

*Source: Adapted from MCTIGHE and WIGGINS 2004 by NATHAN AND HALVERSTON 2005.*
benchmark goals for each student, continuously assessing what their students have learned and achieved. It is important for the Teacher to meet with the Fellow early in the year to discuss these content standards so that both parties are aware of and agree on the learning goals for the year.

Be mindful that students, Teachers, and Fellows all come to school with diverse experiences and ideas. For example, Native American students, who might spend a majority of time on reservations, will bring significantly different experiences and ways of thinking and learning about the world than inner-city African-American, Hispanic, or Caucasian students. Where we come from affects the way we see and understand the world; hence, the curriculum we implement should be culturally sensitive and responsive (Stephens 2003).

The characteristics and strengths of culturally responsive science curricula as adapted from Stephens (2003) include:

- Begin with topics of cultural significance and involve local experts.
- Link science instruction to locally identified topics and to science standards.
- Provide substantial opportunity for students to develop a deeper understanding of culturally significant knowledge linked to science.
- Incorporate teaching practices that are compatible with the cultural context and focus on student understanding and use of knowledge and skills.
- Engage in authentic assessment, which guides instruction, taps into a deeper cultural and scientific understanding, and sharpens the students’ reasoning and skills related to standards.
- Recognize and validate what children know and then build upon that knowledge toward more disciplined and sophisticated understanding from both indigenous and Western perspectives.
- Tap the expertise of local people and link their contemporary observations to a vast historical database gained from living on the land.
- Address content standards from multiple disciplines.
- Consider providing an article or other material for the Teacher to prep the students before you come into the classroom.
- Begin with an icebreaker, perhaps a get-to-know-you game.
- Share a story that describes your personal and professional path, your roadblocks, and your sources of inspiration.
- Use a hands-on activity to continue to engage students and show them a glimpse of your work.
- Allow time to reinforce the main point of your lesson and for final questions.
- Use simple formative classroom assessment tools to evaluate your lesson.
- Make yourself available to the Teacher and/or students by sharing your email address or other contact information.
- Recommend articles, movies, websites, or other resources that the Teacher can use to follow up on your presentation.

“...to have these students understand the research process. By using...the textbook and hands-on experiences with guest lecturers, communication with research specialists, and field interactions, I was able to help my students advance [their] scientific thought processes to create their own research projects.”

—GK–12 Fellow

his or her research and STEM expertise into the
curriculum to teach a particular standard. The
next step is to determine the benchmarks or other
evidence which will indicate that the student has
achieved the goal or standard. With these learning
goals and benchmarks in mind, Teachers and Fellows
develop inquiry-based and other types of activities
that will improve the students’ understanding of the
specific concepts taught.

The Teacher and Fellow should also consider how
these activities would benefit the Fellow—for example,
by providing an opportunity to practice communicating
certain aspects of his or her research. Once the Fellow
has developed a lesson plan, he or she should meet
with the Teacher to run through the lesson before
presenting it to the students. Teachers can give
Fellows critical feedback regarding whether the lesson
is at the appropriate skill level. They can also give tips
on classroom management. Lesson plan development
is ongoing throughout the year and requires constant
open communication between the Fellow and Teacher.
A GK–12 Teacher described this collaborative and
dynamic planning process with Fellows:

“We lesson plan together. We communicate
via email and text outside of the school day.
I make suggestions and modify lessons as
needed. I listen to their input for lessons
and try to build my schedule around their
strengths. We laugh a lot together to relieve
the daily stress of middle school life.”

Another GK–12 Teacher said:

“I look at the big picture of a unit or concept
and then break it into pieces and see which
ones fit me and which ones fit the Fellows.”

See Appendices 6.2 through 6.4 for lesson plans,
developed by GK–12 Teachers and Fellows through the
backward-planning process, that link STEM content
and research to educational standards.

KEYS FOR SUCCESS: BRINGING RESEARCH
TO CLASSROOMS

- Teachers and Fellows should work together
to tailor inquiry-based and other research
experiences to meet the specific interests,
backgrounds, and needs of their students.
There is no one-size-fits-all inquiry-based
approach. Keep in mind the characteristics
and benefits of culturally responsive
science curricula.

- Fellows should expose students to STEM
careers by sharing personal experiences
that have shaped the Fellows’ careers as
scientists, bringing current events into
their field of research, and explaining the
day-to-day reality of life as a scientist.

- Fellows can bring technology into the
classroom by integrating common
classroom technologies with resources and
technologies available from the university,
such as STEM software, library databases,
and web-based curriculum materials.

- Teachers and Fellows can bring research
to the classroom by guiding students in
conducting long-term student-directed
research projects.

- Teachers and Fellows should meet early in
the year to review the content standards
for the course and to identify where
the Fellow’s research can fit into the
curriculum.

- Before presenting a new lesson, Fellows
should meet with Teachers to get feedback
on effective teaching and classroom
management strategies.
A sixth-grade classroom worked with a Fellow who was using light emitting diodes (LEDs) to conduct research on water purification. The Fellow wanted to show students that engineers also have to think about costs when conducting research. Students were given materials such as an empty water bottle, cotton balls, activated carbon, clear plastic cups to collect filtered water, and water colored with red food coloring. This activity introduced the basic operation of a water filter to students, and helped them understand that both the design itself and the cost of the design affect the way that research is conducted. Upon advice from the Teacher, the Fellow also decided to incorporate math into the activity, which would help the students to practice a sixth-grade math standard of calculating taxes. The Fellow presented background on different forms of water filters and why it is important to have clean water. He then challenged the students to design and build a cost-effective water filter. Students simulated the real-world experience of engineers by “buying” their supplies and designing and testing their filter, all the while keeping in mind cost-effectiveness. This effective inquiry-based lesson engaged the students and gave them the opportunity to ask questions, test their hypotheses, see results, and test again, while being aware of the cost-effectiveness of their design.

Another Fellow in a middle school classroom showed students how he created a cysteine oxidation prediction project on his computer. During his presentation, he displayed a protein that is oxidized and one that is not and he ran his project to showcase how technology can be utilized in engineering and computer science.

Since 1998, the State University of New York College of Environmental Science and Forestry (ESF) has partnered with local high schools through the ESF in the High School outreach project (ESFHS). Through this partnership, qualified high school students have the opportunity to (1) experience college-level course work and earn college credit while still in high school, (2) explore complex current environmental issues, and (3) learn about career opportunities in fields related to environmental science and engineering.

From 2004 to 2010, the ESFHS project grew through the support of an associated NSF GK–12 project that supported 52 Fellows. Fellows interacted with more than 600 students each year from more than 30 urban, suburban, and rural high schools across New York who enrolled in The Global Environment, a research-based course that allows students to explore a range of environmental and social issues.
GK–12 Fellows were placed in “home schools,” where they collaborated with Teachers to infuse scientific research and inquiry-based learning into the classroom, primarily by guiding students in designing and carrying out yearlong independent research projects. Fellows collaborated with Teachers to teach students transferable research skills in literacy, communication, and analysis. To facilitate the research process, the GK–12 Fellows published a comprehensive research guide for high school students and Teachers (Stewart et al. 2009). In addition to mentoring students, Fellows led inquiry- and research-based activities called “road shows” at other high schools participating in ESFHS. Teacher Megan Wolfe described the impact of the Global Environment course:

“My students learned so much from their ESF in the high school course. Not only does it expose students to a college-level curriculum, but it provides them with the tools to conduct a college-level science research project. This is an incredible opportunity for high school students; not many courses allow them the chance to design, implement, and analyze their own student-driven original research that they eventually present in a college setting. They’re provided with the opportunity to interact with and learn from college professors and graduate students both on and off the ESF college campus.”

At the end of the school year, students present their research projects at the much anticipated Environmental Summit, a research conference held at the university and attended by graduate students, faculty, and other high school students and teachers. This unique professional experience gives students the opportunity to share their research findings in formal talks and posters and to receive feedback from expert scientists from the campus community. In 2009, over 50 independent research projects were presented by students at the Environmental Summit on a broad range of topics, including (1) the impact of suburbanization on the diversity and abundance of local bird populations, (2) the relation between El Niño events and snowfall in Central New York, and (3) an analysis of recyclable material in the high school waste stream.

The ESFHS project has provided a natural transition for high school students to enroll in undergraduate degree projects in STEM at ESF and other universities. In 2010, 29 former ESFHS students were enrolled as freshman at ESF, making up 10% of the freshman class. Matt Williams, a principal in the Syracuse City School District, described the role of ESFHS in the local community:

“ESFHS is an integral part of our vision for the future of our children. They have become a close collaborator and have dedicated themselves to realizing a comprehensive college preparatory project at the Institute of Technology. This is the result of a project that doesn’t just offer college-credit-bearing courses, but offers the commitment, the time, and the passion for our city’s students to realize their true potential.”

Ultimately, the ESFHS project seeks to develop students and citizens who have a solid understanding of science and a sense of wonder and appreciation for the Earth as a system.
INITIATING NEW SCIENCE PARTNERSHIPS IN RURAL EDUCATION

Mississippi State University
http://www.gk12.msstate.edu

The Initiating New Science Partnerships in Rural Education (INSPIRE) project between Mississippi State University and three rural school districts in North-Central Mississippi focuses on technology-supported inquiry-based learning in the earth and space sciences for 7th- to 12th-grade science and mathematics classrooms. This interdisciplinary project recruits 50 Fellows from four STEM disciplines (geosciences, physics, chemistry, and engineering) and partners them 2:1 with a 7th to 12th-grade Teacher. The innovative aspect of the project includes the use of technologies such as spatial analysis platforms (e.g., Google Earth and ArcGIS Explorer), GPS units, robotics, electronic handheld weather stations, proScope microscopes, benchtop scanning electron microscopes, and gas chromatographs during the classroom implementation of graduate student research.

Fellows’ scientific research is incorporated into the classroom through the use of technology and inquiry-based learning. The classroom experience is extended beyond our nation through international training experiences for Fellows and Teachers during which they can partner to visit one of four international locations (Australia, Poland, England, and the Bahamas) to conduct research and build international partnerships.

During the 2010–2012 school years, 20 Fellows worked directly with eight Teachers and approximately 1,200 students in six classrooms. Two hundred sixty-three lesson plans in physics, algebra, geometry, chemistry, robotics, botany, earth science, physical science, and middle school science were created and implemented by the Fellows and Teachers. Six Fellows and two Teachers visited all four of the international research locations and conducted research in hydrogeology systems, the use of GIS in wildfire prevention and management, prevention of icing on aerodynamic vehicles, replenishment of eroding beach environments, and the use of GIS in analyzing water flow patterns across various surface areas. Some examples of Fellow-led classroom lessons include: (1) “Potato Launcher Energy Lab,” in which students determine the correct angle to fire a potato the farthest out of a class-created cannon; (2) “Weather Elements and Instruments,” during which students use handheld SkyMaster weather stations to collect data in order to make weather predictions; (3) “Measuring Body Angles,” to learn how a body’s angles play a role in determining the ergonomics of developing furniture products; (4) “Metals Across the Periodic Table,” in which students are able to burn samples of various metal solutions to identify the type of metal on the basis of the flame color emitted; and (5) “The Information in the Spectrum of Light,” which allows students to analyze the spectra of visible light from various objects and samples of gas.

In addition, a Geographical Information Systems (GIS) day was held each year at the university, with approximately 200 INSPIRE 7th- to 12th-grade students participating in the events. Local students
engaged with the GIS software and completed small-group activities developed by the Fellows and aimed at exploring societal issues associated with natural disasters (e.g., tornadoes, earthquakes, floods, hurricanes, severe weather).

“Implementing my research into the classroom definitely changed the way I have thought about the process involved. Not only have I had to explain to approximately 120 eighth graders what I am doing, [but] I have also had to write it out in a manner that is easy to understand. I will also admit that the questions my students have asked about my research have helped me to refine my questions.”

—INSPIRE Fellow

“The students were well entertained and inspired! There was not enough time to accommodate each student's desire to use the microscopes! I believe that most students’ impressions of science increased; their desire to explore their world increased. The hands-on and visual nature of the activity was a key factor....”

—INSPIRE Teacher

“Our INSPIRE Fellow brought in real-world experience by sharing his trip to mammoth cave with the students. The awesome part [is that] he not only used the trip to review a couple of geology terms, but related the processes of cave formation to the chemistry lesson we had a couple of weeks ago.... He told the classes, ‘See, this stuff really happens in the real world. You are learning it for a purpose....’ The focus on research-based lessons was excellent this year... There are many differences between an INSPIRE classroom and a non-INSPIRE classroom. INSPIRE-based classes offer real-world perspectives.”

—INSPIRE Teacher

**FOR MORE INFORMATION**

- BSCS and IBM. 1989. *New designs for elementary school science and health*: A cooperative project of Biological Sciences Curriculum Study and International Business Machines. Kendall/Hunt, Dubuque, IA.
FOR MORE INFORMATION


TO BE CONSIDERED PROFICIENT in science, K–12 students need to know about and interpret scientific explanations about the world, generate and evaluate evidence, understand the nature of science, and participate in science practices (NRC 2007). Partnerships between science Fellows and K–12 Teachers are ideal for helping students reach proficiency in these areas. Fellows can contribute knowledge about science and science practices, while Teachers can help frame the students’ experiences appropriately through pedagogy and experience with K–12 students. However, science and science-related experiences conducted within any classroom are inherently limited in terms of mirroring real-world experiences. Supplementing such instruction with experiences beyond the walls of the classroom not only can help students gain science proficiency, but also can be instrumental in promoting interest and engagement with science (NRC 2009). In turn, a short-term science interest can lead to the building of “science identities” and the pursuit of scientific careers. Many out-of-classroom activities also come with the opportunity to participate in service activities, which can foster positive attitudes toward civic engagement for a lifetime. Such experiences deeply affect not only the K–12 students, but also the participating Teachers and Fellows.

In this chapter, we explore how to (1) expose K–12 students to informal science education settings, such as museums, science centers, and aquariums; (2) connect K–12 students to the community with the help of government organizations and nonprofits; and (3) encourage K–12 students to participate in activities such as science festivals, summer camps, and field trips. First, we will consider best practices and examples of GK–12 projects that partner with informal science learning venues, government agencies, and/or nonprofits. Next, we will consider best practices and examples of participation in, and implementation of, out-of-classroom activities such as science festivals, science fairs, and field trips.
PARTNERSHIPS OUTSIDE OF THE SCHOOL SETTING
Many GK–12 partnerships are outside of the school setting, involving nonprofit organizations, government agencies, and informal learning venues such as museums and science centers. Such partnerships allow both Fellows and K–12 students to experience a number of benefits that formal venues may lack, such as experiences that increase interest in and identify with STEM, promote exposure to STEM work settings, and provide the opportunity to connect with the local community in a service context.

Partnerships with Informal STEM Learning Environments
Science, with its specialized language and practices, can be intimidating for K–12 students—particularly girls, individuals from socioeconomically disadvantaged backgrounds, and ethnic minorities (e.g., Bevan et al. 2010, NRC 2009). Students must undergo what Aikenhead (1996) has referred to as “border crossings” from their own culture into that of science if they are to be successful in STEM endeavors. Informal venues such as museums, aquariums, zoos, and science centers excel at helping students negotiate these border crossings. An emphasis on real objects, connections between culture and science, and a high degree of learner control are critical features of experiences at such institutions. Thus, informal STEM experiences can lead to sustained STEM interest, identity, and learning (NRC 2009). In turn, individuals who identify with and feel positively about science are more likely to pursue science hobbies and careers (Brickhouse et al. 2000, Aschbacher et al. 2010).

Many GK–12 projects incorporate field trips to informal venues as supplementary experiences for K–12 students, but some projects form deeper partnerships with such institutions. The University of Colorado’s GK–12 project ECSITE (Engaging Computer Science in Traditional Education), for example, worked with the Denver Museum of Nature and Science to engage Native American K–12 students in STEM-related museum activities. During a two-week summer internship, the students (in conjunction with a GK–12 Fellow) experienced projects that connected traditional native knowledge with science, designed educational displays, and shadowed museum professionals to learn more about what they do in their careers. The students worked diligently to prepare a proposal for an interactive touch screen display of a diorama about the Cheyenne people, as well as for other areas in the museum. The level of cooperation and teamwork exhibited by the students was impressive. They worked together and gave a formal presentation at the end of their two weeks. For some, this was their first time giving such a presentation. The GK–12 Fellow, also a Native American, shared with these students how he had struggled in school but worked hard. In the second year of the project, one of the previous workshop students was rehired as an intern. This student used the proposal from the previous year to create an interactive display to view through Google Sites and QR (Quick Read Code) for mobile devices. Following are some participants’ comments about the project:

“It was really great to hear from other Native people that college is not out of my reach. I will be the first person in my family to go to college, and in my whole life I have never been encouraged to pursue a college education, until now.”

—Xavier, 17, Navajo

A University of Wyoming summer camp student shows off polymers that he created.

Watershed Integrated Science Partnership (WISP) K–12 Teachers explore the coast of Massachusetts.
“Having Native people as the Teachers for the workshop made us feel comfortable. We didn’t feel like we had to explain ourselves, because they already knew where we were coming from.”

—Westley, 17, Seminole and Chickasaw

“At times, it got boring, but over time I thought, wow, I didn’t know that! I’m glad I got to know stuff that I didn’t know before. Since I’m going out into the real world, now that I know this, I can apply it.”

—Jessica, 16, Osage, Eskimo, Blackfeet, Cherokee, Salish, and Kootenai

“Native people have different ways of doing things. In school, teachers make us learn things their way and explain things the way they want us to. During this workshop, we were allowed to work on something that we were interested in and we were allowed to work how we wanted to.”

—Josh, 16, Navajo

Other projects integrate the expertise of informal educators into curriculum development efforts to bring elements of the informal environment into formal K–12 classrooms. For example, the GK–12 GeoKids LINKS project at Saint Joseph’s University partnered with the Wagner Free Institute of Science (WFIS) to develop K–5 science lessons for use in the School District of Philadelphia. Fellows formed teams with elementary school teachers and WFIS educators to create semester-long units with natural science themes. Such pairings between formal and informal venues follow best practices described in the report “Making Science Matter: Collaborations Between Informal Science Education Organizations and Schools” (Bevan et al. 2010). In another example, Boise State’s GK–12 project partnered Fellows with several local science centers (the Morrison Knudsen Nature Center, the Foothills Learning Center, and the Boise WaterShed Environmental Education Center) to develop and deliver educational activities. Classes from throughout the region visit the science centers to participate in activities developed and delivered by Fellows.

**Partnerships with Nonprofits and Government Agencies**

GK–12 activities in the setting of a government agency or nonprofit organization offer K–12 students the chance to experience science firsthand in real-world settings. Many projects carried out in partnership with these organizations are projects that benefit society and therefore provide “service learning,” which combines academic work with civic engagement (Bringle and Hatcher 1996). Service learning has

**RECOMMENDATIONS:**

**INFORMAL LEARNING ENVIRONMENTS**

- Recruit energetic and engaging scientists to become Fellows; their enthusiasm will shine through to the students.
- Plan events well in advance, and give time to advertise the event.
- Let the students direct the themes of the projects; they will be more engaged if they care about the topic.
- Use existing resources and organizations to leverage activities. There is no need to reinvent the wheel.
- Know your audience, including its age range and previous experience.
- Create hands-on activities.
- Plan for transportation well in advance and assign a point person to organize the fare.
- Consider recruiting outside help with organizational details such as permission slips, transportation, and chaperoning where applicable.
Several benefits for participating students, including increasing their sense of self-efficacy, spurring them to further their education, and enhancing their problem-solving skills (e.g., Chung 1997, Tannenbaum 2007). An additional benefit that GK–12 activities in these settings offer K–12 students is exposure to STEM careers and professionals, who can serve as role models and mentors. Such exposure may increase the likelihood of participation in STEM careers (Brody 2006).

In one example, the WISE (Watershed Interdisciplinary Science Education) GK–12 project, based at Christopher Newport University, partnered GK–12 Fellows with high school students and Teachers to develop field sampling techniques for the Chesapeake Bay. Results were entered into a database and were used to help the City of Newport News Departments of Engineering and Waterworks monitor and manage pollution. Then, with the assistance of personnel from HR STORM (a committee of the Hampton Roads Planning District Commission), students interpreted and presented their scientific findings to their local communities, thereby helping to inform practices to improve the area’s water quality.

The University of Utah Project WEST (Water, the Environment, Science and Teaching) partnered with Utah Division of Wildlife Resources (UDWR) biologists, Tracy Aviary Wetland personnel, and wetland conservation experts to engage students in wetland conservation issues. Fellows and K–12 students participated in wetland restoration activities, collected scientific data, and developed and implemented a conservation plan for the wetland after presenting their recommendations to the UDWR.

Preparing Fellows for Working in Informal Environments

Preparation for teaching in informal environments such as museums and aquariums is similar to that required for teaching in formal environments, but differs in important ways. In informal environments, presenters must reach an open audience that has multiple entry and exit points into the lesson. Thus, activities structured for informal environments need to use different engagement strategies from those used for formal environments and must allow for people “dropping by” to easily engage with the activity. Some GK–12 projects have established training courses or workshops based on the NSF-funded COSEE (Center for Ocean Science Education Excellence) California course called “Communicating Ocean Sciences.” To prepare Fellows for informal environments, some GK–12 projects have excerpted portions of the COSIA (Communicating Ocean Sciences to Informal Audiences) version of this course. (All course materials and training modules are available at http://www.coseeca.net/projects/communicatingoceansciences/cosia/.) For example, the GK–12 Socrates project at the University of California–San Diego requires Fellows to present science activities at the San Diego Festival of Science and Engineering, an informal event that reaches over 55,000 people. The Socrates project manager has helped prepare Fellows for participation with training modules drawn from COSIA.

**Keys for Success: Other Than School Partnerships**

- Involve representative stakeholders from the outset of the project, making sure that multiple views are incorporated into planning.
- Be aware that institutional cultures may differ.
- Plan appropriately the time it takes to form collaborations.
- Convene regular stakeholder meetings throughout the project.
- Build in flexibility in partnership plans to allow for possible changes in funding levels, staffing, etc.
INFORMAL OUT-OF-CLASS SCIENCE ACTIVITIES

In addition to partnering with informal science learning venues, government agencies, and nonprofits, Fellows and their K–12 students have participated in a wide array of other out-of-class experiences, such as science festivals, field trips, science summer camps, and science fairs, in which scientists are likely to interact with not only K–12 students, but the public in general. In these endeavors, scientists should be aware in advance of potential pitfalls to public engagement with science.

Although scientists often complain about the public's scientific illiteracy, they fail to recognize that they in turn have a poor understanding of the public (Mooney, 2010). Scientists are generally regarded positively by the public (Pew Research Center, 2009), but there is a list of science policy issues that reveal historically poor engagement between scientists and the public on topics such as nuclear waste management, genetically modified food, climate change, and the teaching of evolution in public schools. The old adage “Know your audience” has particular relevance for scientists attempting to engage with the public. Scientists can best share their knowledge when they respect the cultural differences between the scientific and public enterprises and take into account the value systems that inform public opinions and viewpoints. Without such consideration, scientists run the risk of doing more harm than good.

There are many resources for effective science communication and engagement with the public, including the AAAS website http://communicatingscience.aaas.org/, which has links to additional resources on public outreach and communication basics. (See “FOR MORE INFORMATION” at the end of this chapter for additional resources.)

In this section, we will explore several nontraditional partnership opportunities in which scientists can interact with K–12 students and the broader community through science festivals, field trips, science summer camps, and science fairs.

Science Festivals

Science festivals provide a free-learning experience aimed at sparking interest in science, technology, engineering, and math. Their open format, allowing anyone to peruse hands-on science demonstrations, appeals to casual learners of all ages. When this is done well, it feels more like fun than learning. In one example, participants in the NYU-Poly GK–12 project designed interactive mechatronics demonstrations at the inaugural USA Science and Engineering Festival. Fellows were trained and screened prior to the event to ensure effective communications skills (Abaid et

“...it was one of the most life-changing experiences for me because I was able to watch a large number of students get excited about science, technology, and engineering in a short period of time.”

—GK–12 Fellow at NYU–Poly about the USA Science and Engineering Festival

KEYS FOR SUCCESS: SCIENCE FESTIVALS

- Prescreen and/or train Fellows for good communication and delivery skills prior to public engagement (e.g., videotape and critique presentations in advance of the informal outreach event).
- Survey participants for evaluation purposes (e.g., how well was the message received?).
- Know your audience (e.g., use pictures if expecting young children).

KEYS FOR SUCCESS: FIELD TRIPS

- Assign a point person—preferably a parent or Teacher—to communicate with those responsible for transportation.
- Partner Teachers with the right field experts to coordinate logistics. For example, plan a harbor trip according to the timing of the tides and with boat safety issues taken into account.
- Use local partnerships to leverage activities. Introduce Teachers to local connections and resources, including nonprofit organizations.
- Appreciate that experience has its own educational value: Minimize formal educational activities during field trips.
al. 2011). They were videotaped to allow for self-reflection on their presentation skills, as well as critiqued by faculty members. Only those students who demonstrated engaging delivery skills were invited to participate in the public event. The exhibit included several interactive projects: a mechanical advantage apparatus (i.e., pulleys), a robotic fish, a LEGO image scanner, an audio-enabled legged robot, and iPod-controlled devices. Child and adult visitors were free to participate in whichever activities piqued their interest. The Mechatronics Mania exhibit reached an estimated 2,500 people in two days.

**Field Trips**

Learning about the world through books and lectures has its virtues, but field trips provide experiential learning that cannot be imparted in the classroom. Field trips may help students connect with their native surroundings, especially local ecosystems. Many GK–12 projects use field trips extensively to promote such connections. For instance, the Watershed Integrated Sciences Partnership (WISP) GK–12 project at the University of Massachusetts–Boston pursued several extracurricular science activities, including field trips, laboratory tours, citizen science projects, and boat cruises, to “foster a sense of connectedness” to the university’s local aquatic surroundings. UMass Boston brought both Teachers and students on boat tours of the Boston Harbor. With the Teachers, they sampled copepods (small aquatic crustaceans) from the water and designed mapping and velocity exercises that could be incorporated into classroom curricula later. However, when the students were on the boat, they were not required to complete experiments or listen to lectures. Rather, the value of the trip was in the experience itself. Some children had never been on a boat, and they described the boat ride as their best field trip of the year.

Similarly, middle school students in the SPICE (Science Partners in Inquiry-based Collaborative Education) GK–12 project at the University of Florida were taken to the Gulf of Mexico, where they explored intertidal marshes and rummaged through biological material from a dred. Most of them had never seen the ocean or pondered tides—much less experienced them. For these students, the benefits of such trips can be profound; on two separate occasions, for example, a student exclaimed that the trip had been the “best day of my life.”

**School Yard and Near-Vicinity Activities**

It is not always necessary to travel in order to receive the benefits of field experiences. School yards and neighboring areas can provide ample opportunity for outdoor science exploration without the costs and logistics required for field trips. For instance, the East Tennessee State University GK–12 project created an outdoor classroom right on the school grounds, with outdoor areas for classroom instruction and a fossil dig pit. Near-vicinity projects can also serve to foster community engagement, since these activities can focus on local issues of importance. For instance, several GK–12 projects have restored local ponds, creeks, and greenways within walking distance of the school, linking students to their natural environments, even within city limits. At the Washington State
University Vancouver GK–12 project, Fellows had students work with community groups to restore nearby Mill Creek. By planting 14,000 trees along the banks of this fragile creek, not only did the students contribute to local restoration efforts, but they also learned about the ecology of a river system in their community.

Still other near-vicinity projects link to issues of sustainability. GK–12 Fellows at Arizona State University worked with local high school students to transform an ugly vacant lot next to their school into a field of sunflowers. The sunflower seeds that they subsequently obtained were then harvested to create sunflower oil that was sold at the local farmer’s market and biodiesel to power a solar–biofuel hybrid car designed and put into production by the high school’s sustainable-design club. Sustainability education for high school students greatly benefits from hands-on transformational learning experiences by means of which students begin to appreciate the connection between land use and energy consumption right in their backyards.

**Summer Camps**

Summer break provides a rich opportunity for extended science education. Science camps take advantage of this time to enrich learning with hands-on activities that reach beyond the traditional curriculum. Designing a summer camp de novo can be a daunting task, so one should first consider partnering with established summer camp organizations to leverage their expertise in camp logistics. That way, the GK–12 Teachers and Fellows can focus instead on providing science content and science mentors to camp participants. However, some GK–12 projects, such as the University of Wyoming’s Science Posse project and the University of South Florida’s STARS project, did develop several science summer camps for K–12 students de novo. The University of Wyoming team partnered with established organizations to delegate chaperone and administrative responsibilities in subsequent years. (See exemplar at the end of this chapter.)

**KEYS FOR SUCCESS: SUMMER CAMPS**

- Whenever possible, partner with existing successful summer camps and work with them to incorporate science content.
- Choose a theme for the science activities to provide cohesion.
- Design science activities to be hands-on.
- Have extra science activities ready in case one activity ends prematurely. Also, schedule nonscience time, such as playing games or sports.
- If designing a summer camp from scratch:
  - Advertise well in advance (e.g., in January) to ensure a full student cohort.
  - Hold the camp for three to six days if possible. Shorter periods do not allow children to absorb the science, while longer periods can lead to disengagement.
  - Assign a transportation coordinator, e.g. a parent or Teacher.
  - Assign a risk manager to coordinate permission slips and deadlines, first aid, emergency contacts and plans, allergy information, and medical forms.
  - Include chaperones in addition to scientists; consider recruiting undergraduate students, who can serve as role models and contribute enthusiasm.
  - Ask some parents to pay tuition for the camp to offset the costs, but provide scholarships for students from low-income families.

Students launch their Angry Bird in an exploration of parabolic motion at the University of Wyoming summer camp.
The STARS GK–12 project held weekly meetings to plan its summer science camp curriculum. Fellows were paired with Teachers to ensure a good combination of science and pedagogy before a summer camp activity was deemed ready for implementation. In addition, the STARS project took the students’ interests into consideration in planning such themes as “Young Inventors,” “Green Scientists,” and “Mission Space.” To ensure a diverse student population, the project offered scholarships for students from low-income families.

The Science Posse GK–12 project designed four-day science summer camps for middle school students. The first year, students were given an inquiry-based science mystery called “CDC: Wyoming ~The Twin Pines Mystery Illness,” in which several groups of middle school students worked on different pieces of the mystery. The activity incorporated problem-based learning and collaborative learning, both of which are highly effective approaches for stimulating engagement in science and science learning.

Science Fairs
Science fairs allow participants to develop and test hypotheses of their own creation—in other words, to actually experience science. Thus, science fairs are an ideal context for GK–12 Fellows to pair with K–12 teachers to guide students in developing and carrying out experiments. In one example, the University of Wyoming GK–12 Science Posse designed a permanent repository of tools for developing science fair projects that can be used by Teachers long after the partnership concludes. Fellows created videos, examples, and how-to presentations to aid in designing science fair projects and placed these resources on a website (http://www.uwyo.edu/scienceposse/science-fair/index.html). Fellows presented advice for science fair projects and spoke with students one-on-one to develop hypotheses and appropriate methods for their individual projects.

**KEYS FOR SUCCESS: SCIENCE FAIRS**

- Encourage students to make their projects personal—aligned with their interests.
- Coordinate with the Teacher in advance to know what level of advice is required. Have students already chosen their questions? Do they need advice about the scientific method?
- Prepare visual materials in advance to cover all the hallmarks of a science experiment: the question or hypothesis, variables, controls, repetition, the presentation of data, etc.
- Provide sample science fair projects.
Science Posse has implemented successful summer camps for 15–40 students each year since 2009. The first summer camp was a four-day, hands-on event. The theme for the inaugural year was “CDC: Wyoming ~ The Twin Pines Mystery Illness,” related to an inquiry-based scenario of citizens dying of an unknown disease. Science Posse challenged the students to form several groups to work on different pieces of the puzzle. Only once the teams reconvened did they have all the clues necessary to solve the forensic mystery.

By 2010, Science Posse summer camps were so popular that all 40 spots were filled within a week of opening registration and they quickly filled a waiting list. In their second year, the team based the camp theme on a popular TV show, “Myth Busters,” that students could identify. Every Science Posse Fellow created a hands-on activity debunking a popular myth from his or her field, using inquiry-based and hands-on activities.

By 2011, Science Posse had teamed up with two local education organizations: Teton Science School and the University of Wyoming School of Energy Resources. The partnership allowed the summer camp to reach more students, extend the camp from four days to six, and expand the age range to 9th and 10th graders for one of the two camps. The themes for 2011 included “Science in Motion” and “Biodome on Mars.” In response to the interests of young students, the 2012 Science Posse summer camp themes were “Science on the Silver Screen” and the inquiry-based “Summer of Curiosity.”

The Science Posse project plans each summer camp, factoring in unanticipated changes in activity scheduling in case activities run too long or not long enough. The planners are also careful to break up the science activities with games or sports, to keep the children from being too sedentary or losing interest. Fellows often find themselves exhausted after summer camp ends, so it is important not only to choose the most enthusiastic Fellows to participate in the camps, but also to allow time to recover after the camps.

To keep students interested in the science activities, Science Posse Teachers and Fellows developed several strategies: (1) they choose a theme for the event and tailor that theme to the interests of the students; (2) they ensure that each activity has a set goal so that both the students and the instructors know what is expected and when the activity is complete; and (3) they recruit students on the basis of their professed interest, rather than opening up the camp to all students. To find the students with a true interest in science, they ask that each applicant submit a letter of interest explaining why he or she wants to attend the camp.

Although the effort it takes to plan and execute a successful summer science camp is extensive, the opportunity for young students to gain hands-on experience with experimentation, science, and engineering cannot be understated. It is often these informal science activities that inspire future scientists and allow them to stretch their science skills well beyond what is available in the classroom setting.


PREVIOUS CHAPTERS HAVE DISCUSSED activities in and out of classrooms in the United States. International experiences and collaborations provide many additional and unique opportunities to GK–12 participants. Through these experiences, Fellows and Teachers can learn about the world, how to function in a global society, and how to develop networks for future collaborations. Preparing a globally engaged workforce is of utmost importance, as was detailed in a workshop hosted by the National Science Foundation in 2006 and titled “Assuring a Globally Engaged Science and Engineering Workforce” (www.sigmaxi.org/global).

This chapter focuses on the advantages of including international opportunities in GK–12 projects. In particular, it looks at benefits for Fellows and Teachers, how to establish international collaborations, requirements and logistics for traveling abroad, and what to do during and after international trips.

Some of the material included in this chapter comes from the Proceedings of the GK–12 Project’s Workshop on International Experiences in Science, Technology, Engineering and Mathematics (STEM), a workshop that took place at the National Science Foundation in 2007. Yet, international experiences are not required in the GK–12 approach. Indeed, international experiences are not
the same for each type of participant, so specific activities should be determined by individual projects. It would be difficult to standardize international experiences for all projects, all Fellows, and all Teachers. Leaving the design of an international component up to each project is simply a creative option.

WHY CONSIDER AN INTERNATIONAL COMPONENT
In its report “Globalization of Science and Engineering Research: A Companion to Science and Engineering Indicators 2010,” the National Science Board describes the rapidly changing nature of the science and engineering enterprise and the need to engage in international partnerships to keep the United States globally competitive. The National Science Foundation Strategic Plan (2011–2016) also emphasizes the importance of increasing international collaborations and partnerships. The promotion of international collaboration, the elimination of barriers that prevent collaboration, and the increased need to encourage jointly funded bilateral and multilateral projects are integral components of this plan. As STEM expertise and infrastructure advances throughout the world, it is expected that international collaborations will benefit all participants involved and will result in a larger impact and more innovation in science and engineering worldwide.

How Fellows and Teachers Benefit from International Experiences
Connecting Fellows to researchers and academic and industrial institutions abroad will increase employment options for the Fellows as well. Connecting Teachers to both Teachers and students in other countries will promote STEM learning in the United States. Exploring teaching methods in other countries could promote exchanges on multiple levels and will encourage the use of new technologies and cybertools. The practical reasons for international collaborations include having access to items, equipment, or facilities not available within the native country, focusing on research related to specific regions of the world, and having access to particular data. In addition, experiencing other cultures is a way to broaden one’s perspective.

Although global engagement should happen at all levels of education and for all participants involved, the NSF GK–12 program supported mostly project directors, Fellows, and GK–12 Teachers traveling abroad. Including international experiences for Fellows and Teachers may bring benefits, but also can present some challenges, such as language barriers, culture clashes, and logistics related to visas and permits. Some of these challenges may be overcome with careful planning and close communication with foreign counterparts.

Models of Financial Support for International Activities
There are a number of support models to expand a GK–12 project internationally, primarily as a result of the variability of each university’s GK–12 project implementation. The main goal of the international component was to support Fellows’ research experiences. However, several projects involved Teachers, and some established connections with K–12 schools abroad. Among GK–12 projects, two main modes of support can be distinguished:

- The NSF GK–12 program provided supplemental funding to GK–12 projects for international activities. Funding was awarded through a competitive process and was also used to involve Fellows and Teachers in the international experience.
- The GK–12 project did not provide supplemental funding, but instead offered a platform for an international experience to operate efficiently.
- The GK–12 project provided a flexible platform for graduate students to develop initiatives at their host schools.

“I have heard people say...that math is a universal language, and after this experience I would have to agree at least to some extent. ...In looking back at my experience in China, I am very thankful to have had the opportunity to participate in this trip...I learned a lot about the similarities and differences between our educational systems, as well as our cultures. As we become more and more of a global society, I believe interactions such as these will help us to have a greater understanding and appreciation for the methods other cultures employ to educate their populations.”

—GK–12 Fellow, University of Colorado–Denver, Transforming Experiences Project
GK-12 projects included experiences in several continents and countries, including Antarctica, Peru, Japan, Thailand, India, China, Tanzania, Panama, Kenya, France, Tahiti, Honduras, Tunisia, Egypt, Poland, Hong Kong, and South Africa. Each trip had a different research focus and target audience, but there were a number of commonalities.

Developing an international partnership is a nontrivial task, as there are many factors to consider that do not arise with the formation of domestic partnerships. If all parties have confidence in the proposed international project, the experience can be extremely enriching for all involved. Anecdotal evidence from previous international projects suggests that such partnerships foster the exchange of important ideas and the development of new resources that can be shared with colleagues across multiple disciplines. At the end of this chapter are short examples.

INITIAL PLANNING
The first step in developing an international collaboration is to identify the purpose of the trip, the country or countries to visit, the potential participants and their foreign counterparts, and the timing of the visit. (Table 8.1 provides a checklist of materials and information for participants before and after the international experience.)

Identify What, Where, Who, and When
The choice of country and specific area within the country will depend on the purpose of the trip and previous collaborations developed by either the university or particular researchers. It is advisable to take advantage of contacts already established. It is crucial to establish direct, personal contact with an individual and institution in the host country early in the development of the project. If there are no previous contacts, preliminary visits can be conducted if the budget allows. These trips serve to develop a level of confidence between the project partners and to explore needs and logistics.

The selection of participants will depend on the goals and format of the trip. How many Fellows and how many Teachers are needed? Will the trip include K–12 students? What are the specifics of the selection process, and will it be competitive? Who will make the selection? What financial support is offered to the participants, and what do they have to provide? What are the reporting requirements for participants?

The attitude of the Fellows’ research advisors is an important ingredient in the overall success of the experience. The Fellows should be encouraged to brief their advisors frequently on the goals and duration of the trip and to present a plan for maintaining progress in their graduate degree projects. Ideally, the research advisors will see the value of the trip and perhaps offer advice and contact information.

Define the Purpose of the Trip
Major goals for GK–12 international trips include (i) providing research exchange and collaboration

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<tr>
<th>BENEFITS OF INTERNATIONAL EXPERIENCES</th>
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<tr>
<td><strong>For Fellows</strong></td>
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<tr>
<td>- Learn how research is conducted in other parts of the world.</td>
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<tr>
<td>- Increase adaptability, to work more effectively with scientists who may define and resolve problems differently.</td>
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<td>- Establish more extensive networks and increase linkages for future research.</td>
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<tr>
<td>- Learn techniques and have access to resources not available at the home institution.</td>
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<tr>
<td>- Experience the teaching and learning of science in K–12 schools abroad.</td>
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| **For Teachers**                        |
| - Establish international contacts and lessen professional isolation. |
| - Experience classrooms abroad and learn new or different ways of teaching. |
| - Witness successes and challenges of STEM education in different countries. |
| - Benefit K–12 students at a global level by exchanging ideas and sharing experiences. |
| - Connect with researchers abroad and possibly conduct research with them. |
experiences for Fellows; (2) providing research experience for Teachers; (3) having Teachers and/or Fellows visit STEM classrooms in K–12 schools; and (4) learning about the people, culture, and everyday life in the host country. There are a number of possible organizational schemes for a trip, including the following:

- Individual Fellows are paired with individual researchers at specific universities in the host country. This arrangement allows each Fellow to achieve a deep and specific experience related to a project and to collaborate with a particular researcher.
- Fellows form a single group and the project experience is shared among all. This format may allow for a deeper project impact, but it may leave some Fellows with a suboptimal experience.
- Fellows and Teachers collaborate in a research project with local researchers and connect with local schools. This experience may allow both Fellows and Teacher to experience research and learn about the K–12 system in the host country. If time is sufficient, this scenario might be ideal, but if time is short, it may be difficult to accomplish all planned activities.

The university and K–12 system in the host country, the duration of the trip, and the ease of travel in the country will influence which approach is used. Formats used by other groups, including the examples given at the end of this chapter, can help inform these decisions.

Consider Travel Arrangements

Many universities in the United States and abroad have offices that handle international arrangements for faculty and students. This resource shouldn’t be overlooked when travel logistics are considered.

Obtaining visas and making sure that passports are current can be a lengthy process. Start early! Ticketing will involve many phone calls and emails with a travel agency, often the one approved by the sending institution. If possible, visit the travel agency to put a face to a name; the experience is valuable. Consider the requirements for in-country travel. Do vans make sense, or is it more reasonable to use rail? What is the bus system like, and how expensive is in-country airfare? In many instances, it will be worthwhile to establish a relationship with the destination country’s embassy, which may be able to answer travel questions directly or identify the proper resources.

Lodging considerations will involve determining how convenient the hotel is to the sites to be visited, the price of the hotel, the neighborhood surrounding the hotel, and safety. Are there alternatives to hotels that might make sense for the group, such as hostels, apartments, university housing, or staying with local host families?

Contact the office of risk management on campus and the campus police early in the planning process. Develop a list of emergency contacts for each person going on the trip, and as planning proceeds, supply each one with a list of hotels and dates. Participants may wish to register with the U.S. State Department SMART traveler project (https://travelregistration.state.gov/ibrui). Also, participants will need to review their health insurance plans to determine what will and will not be covered abroad. Emergency health evacuation insurance is available to students and full-time professors at a reasonable rate through an International Student Identification Card (ISIC) (http://www.isic.org). Information about vaccines, as well as other health-related information, can be obtained from the World Health Organization (http://www.who.int/en) or the Centers for Disease Control (http://www.cdc.gov).

Cell phones may be unlocked for international use by cell phone providers, and SIM cards purchased in the host country make it possible to obtain better rates. Internet access may or may not be available at hotels. In some areas, such as Europe, it might make sense to purchase computer devices that allow for mobile Internet access. Although the objectives of the trip might not involve extensive Internet access, Fellows (and Teachers) will want to keep up with their social networks, contact family, and maintain communications with their advisors. Much of this communication can be done inexpensively with Google Chat, Skype, or other Internet-based communication tools.

A preliminary budget based on the proposed project activities should be drafted. This will include a substantial portion for airfare and in-country travel. Questions to ask include: How will accommodations be managed? What are the costs for visas if needed?

“Global scientific collaboration expands the pool of knowledge that belongs to everyone and serves as a tool to improve health, security, and opportunity throughout the world.”
—Subra Suresh, Former Director, National Science Foundation
Will the project cover vaccinations if required? And will there be a contingency fund to meet unexpected expenses?

**Include a Brief Evaluation Plan**
Evaluation can help establish whether the goals and objectives of the trip were achieved. GK–12 international components usually rely on trained evaluators for this purpose. The evaluator may be internal or external to the home institution. Evaluation methods include pre- and post-surveys and interviews of participants, reviews of items such as participant travel logs and planning documents, and direct observation of project activities. Perspectives from the host country and from graduate research advisors, obtained through open-ended questionnaires or surveys, can be valuable as well.

**Consider Sources of Funding**
Of primary concern is the resolution of funding issues for the trip. First, communication with foreign counterparts prior to traveling is necessary to establish connections between potential participants. There are many avenues to investigate in addressing the issue of funding for an international experience. It may be possible to secure funding through university-to-university partnerships, nonprofit organizations, governmental agencies, or special-interest groups. Even if funding is unavailable, it is still important to develop connections with these sources, both domestically and internationally, as they can provide information and infrastructure. Although funding travel may be the primary implementation concern, obtaining reliable information and an effective infrastructure system is necessary for successful implementation; the value of reliable information and infrastructure cannot be underestimated.

Several sources should be considered for funding international trips. Some researchers already have ongoing international collaborations. Projects might consider linking with these enterprises to include Fellows and Teachers. Some federal agencies offer supplements or have projects aimed specifically at funding international activities. For example, NSF’s Office of International Science and Engineering offers the East Asia and Pacific Summer Institutes to support students traveling abroad for the summer. This experience can serve as an initial way to establish links with potential collaborators in the future. The USDA National Institute of Food and Agriculture International Science and Education

**Table 8.1 International Experience Checklist**

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<th>Pre-Departure</th>
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<tr>
<td>Assist participants with travel and medical documents</td>
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<td>Arrange travel logistics as far in advance as possible</td>
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<tr>
<td>Establish contacts with foreign counterparts</td>
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<td>Offer language and cultural training for participants or arrange for translators if necessary</td>
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<tr>
<td>Provide exact project location and information on the key points of contact</td>
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<td>Gather permits required for collecting samples</td>
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<tr>
<td>Convey requirements, responsibilities, expectations, and anticipated outcomes</td>
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<tr>
<td>Have details for medical and travel insurance</td>
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<tr>
<td>Provide emergency contact information for all as well as location of nearest medical facility</td>
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<tr>
<td>Distribute maps, travel itinerary (flight numbers, critical dates, hotel information)</td>
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<tr>
<td>Outline financial considerations</td>
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<tr>
<td>List travel recommendations (what to avoid, how to protect travelers, etc.)</td>
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<th>In Country</th>
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<tr>
<td>Provide on-site orientation</td>
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<tr>
<td>Encourage participants to present their research</td>
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<tr>
<td>Organize regular group meetings of participants</td>
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<tr>
<td>Maintain contact with the home institution through blogs, Skype, emails, etc.</td>
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<th>Return</th>
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<tr>
<td>Disseminate and share experiences broadly</td>
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<tr>
<td>Follow up and maintain linkages with foreign counterparts to keep the collaboration going</td>
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Competitive Grants Project funds projects in a variety of research areas, including biotechnology and genomics, education, environment and natural resources, and food and nutrition. Private companies with business activities in the country or area of interest also may provide funding. Another promising source of funding can come through nonprofit, nongovernmental organizations or other philanthropic organizations: Contact both local and national organizations. National Geographic sponsors a “Young Explorers Grant” project that may be appropriate under some circumstances. Funding for travel to countries with reasonably robust economies may be available from organizations or businesses in the host country. For example, the German Academic Exchange Service (Deutscher Akademischer Austausch Dienst, or DAAD) provides support for American students to travel to Germany.
DURING THE TRIP
Trip participants will benefit from regular group meetings once they arrive in the host country. To gather participants for meetings, consider renting a small conference room in the hotel where the group is lodged. Other meeting formats might involve simply getting together at the start and end of the trip. To share experiences with partnering classrooms back at home, some participants stay in regular communication with the Teacher and K–12 students through email or blogs. A website that highlights trip activities is also a good way to stay in touch with GK–12 partners.

AFTER THE TRIP
Upon their return, many participants share their experiences with K–12 classrooms through interactive presentations. Sharing the experiences after the trip extends and deepens the understanding of the trip for the participants, as well as serving to educate others about study, research, and daily life in other countries. From blogs to online photo books, seminars, and poster presentations, there are many creative ways to disseminate information about the trip. Alert the university or institution’s public information officer to encourage a media story about the trip.

FOR MORE INFORMATION
- National GK–12 website international profiles: http://www.gk12.org/international-profiles
INTERNATIONAL ENGINEERING ACADEMY IN THAILAND

University of Oklahoma, Norman

The University of Oklahoma GK–12 project implemented a seven-day International Engineering Academy (IEA) Teacher–student project in March 2009 and May 2011 at the Prince of Songkla University (PSU)—Wittayanusorn High School, Hat Yai, Thailand. Each year, IEA involved four GK–12 Fellows, two Oklahoma high school Teachers, and two principal investigators. In Thailand, IEA worked with approximately 40 Thai high school science and math teachers from seven national magnet high schools located across the nation. GK–12 Fellows introduced pedagogical concepts related to guided-inquiry learning and then engaged the teachers in one-day guided-inquiry lessons related to engineering. Lessons were developed by the GK–12 Fellows and were related to their graduate research. The lessons also incorporated data collection field trips, with PSU faculty involvement. Finally, Thai teachers taught the lessons to Thai high school students. Importantly, this was an exchange project: The Ministry of Science and Technology of Thailand provided financial support for four Thai teachers to travel to the University of Oklahoma to participate in its GK–12 Summer Engineering Academy.

CUTTING-EDGE RESEARCH IN ANTARCTICA

University of Colorado-Boulder Project EXTREMES
http://www.gk12.org/international-profiles/university-of-colorado-boulder-project-extremes/

Antarctica

Three GK–12 Project EXTREMES Fellows and one middle school science Teacher traveled to Antarctica for a month in 2009–2010 to participate in research related to the Fellows’ doctoral dissertations in ecology and evolutionary biology. The GK–12 team collaborated with well-known researchers from the McMurdo Dry Valleys Long-term Ecological Research group in studies that involved stream ecology, soil chemistry, soil nutrients, and soil respiration. While in Antarctica, the team engaged K–12 students and teachers in this exciting research opportunity through a blog that captured young imaginations far beyond the Boulder Valley (http://cires.colorado.edu/blogs/extremes/). In addition, the team worked on the development of K–12 curriculum that focuses on the cutting-edge research taking place in Antarctica.
EXPERIENTIAL LEARNING IN PERU

University of Alabama
http://bama.ua.edu/~gk-12

The University of Alabama (UA) GK–12 project developed a new relationship with a Peruvian University and aided in the development of an international experiential learning course. In addition, mutually beneficial research projects were adopted, incorporating both students who traveled to Peru and students who researched Amazonian infrastructure challenges from the UA campus. Examples of such projects are the installation of solar panels in rural Amazonian villages and the development of solutions to water and wastewater infrastructure problems. Some of the solutions proposed are under consideration for implementation by the local Loreto government in Peru. Participating Fellows integrated their international experiences into lessons for U.S. students, while a traveling U.S. Teacher published articles about it in the local paper. Several journal articles were published as well.

TRANSFORMING EXPERIENCES IN CHINA

University of Colorado–Denver
http://gk12.ucdenver.edu

The international component of the GK–12: Transforming Experiences project sent GK–12 Fellows and Teachers to China, where they observed Chinese middle school math and science classes, held discussions with Chinese teachers about lesson strategies, and spoke with middle school students. The project also examined the conceptual views of Chinese students with respect to science, the environment, and land. GK–12 Fellows traveling to China also worked on research projects with Chinese faculty and graduate students, including projects that addressed cycle structures, extremal graph theory, Ramsey theory, edge coloring, non-Hamiltonian bigraphs, and impartial combinatorial games.

SOLAR COOKERS IN TANZANIA

Georgia Institute of Technology STEP GK–12

Georgia Institute of Technology STEP GK–12 Fellows traveled to Tanzania, where they implemented a solar cooker that they had designed. The cooker was designed to reduce the need to burn “dirty” fuels, such as wood or kerosene. The students worked with the village’s citizens in order to teach them how to use the cooker, as well as how to construct the simple structure with readily available materials. Project partners included the Science and Mathematics Magnet project at Georgia Institute of Technology, the United African Alliance Community Center in Arusha, Tanzania, several philanthropic groups, and the Westlake High School administration. Participants in project STEP reached out to local organizations and were successful in obtaining necessary funding for the trip.
The University of Houston’s GK–12 project formed a collaboration with Professors Sami El-Borgi from École Polytechnique of Tunisia and Yehia Bahei El-Din from the British University of Egypt. GK–12 Fellow Nathan Howell traveled to Egypt for an entire summer to engage in international research related to environmental pollution by polychlorinated biphenyls (PCBs). The collaboration in Egypt allowed investigations to be conducted into theoretical sorption interactions of PCBs in the environment at a high-performance computing facility. This was not possible before, without the facilities provided by the host institution in Egypt. At the end of the summer, Howell and his host gave a presentation of their collaborative work to engineering faculty and students. He was deeply impacted by the experience from both a cultural and a scientific standpoint. A quote from Howell is illustrative: “I have had my first true collaboration experience, and I hope to have more. The synergy that happens, if the time is used well, is eye opening, and it makes me get excited about the research again, in a way that I have not been quite so much in a little while.”

GK–12 Fellows in the University of Florida's (UF) SPICE project organized a 2009 trip to South Africa. This international experience was unique because the Fellows were responsible for selecting the location, establishing contacts with in-country collaborators, and writing a supplementary proposal request to NSF to fund the trip. They were, however, guided through every step of the process by senior faculty members and by staff at UF’s International Center.

The first step was to determine the trip’s destination and purpose. SPICE Fellows chose South Africa, where UF had already established a strong partnership with researchers at the University of KwaZulu–Natal (UKZN); importantly, faculty and staff at UF’s International Center had been instrumental in establishing that partnership and were eager to work with SPICE through another NSF graduate-training grant.

Fellows met weekly for most of a semester to plan the trip and craft the proposal. They interacted with an NSF program officer, who communicated clearly about how the proposal should be structured, and with several UF faculty members, who provided mentorship in all aspects of the project, but especially with how to locate and communicate with potential collaborators in South Africa and how to write the proposal. Three Fellows who contributed most to the planning became co-PIs on the proposal, an important professional accomplishment.

The primary goal of the trip was for Fellows to conduct research in collaboration with South African scientists so that both groups could learn new techniques and perspectives of science. A second goal was to learn about and contribute to the public education of South African adolescents in science. Because
the theme of SPICE was ecosystem health, all Fellows were broadly interested in environmental issues
and quickly organized themselves into three groups, each focused on developing a short-term research
project on one of three themes: aquatic ecology, terrestrial ecology, and invasive species establishment.
They contacted potential collaborators in South Africa with ongoing projects who would work with them for
approximately three weeks.

Once funding was secured from NSF, planning became intense. All logistics associated with travel were
handled by faculty and staff at UF’s International Center. These people had been involved in the project
from the outset, were strongly committed to it, and accompanied the Fellows in South Africa to provide
support and senior leadership, so most of them were already familiar with the South African study sites,
collaborators, and culture.

The trip lasted four weeks and included 14 Fellows. The first week included seminars at UKZN to
introduce Fellows to the local educational system, the physical and cultural environments, and the
scientific collaborators. Groups of Fellows associated with the three research themes finalized plans. Not
surprisingly, the plans were often quite different than what had been anticipated six months earlier: Fellows
learned about the importance of being adaptable and flexible when conducting international work. Some
Fellows, for example, took advantage of unanticipated opportunities to pursue projects on their own or in
subgroups.

One group worked on population genetics, habitat use, and impacts of environmental contaminants
on Nile crocodiles in St. Lucia Greater Wetland park (iSimangaliso), the largest estuarine ecosystem in
South Africa. Another group worked with the Natal Sharks Board to examine the ecology and physiology
of sharks captured near public beaches. A third group studied the landscape ecology of ant communities.
A fourth group completed experiments on diet selection in native birds, and the final group focused on the
ecological impact of feral cats on native species. To date, this work has resulted in three manuscripts for
publication, three dissertation chapters, four presentations at international conferences, four new grant
proposals, and a position in the Peace Corps for one of the participants.

During the final week of the trip, four middle school Teachers who had been working with SPICE Fellows
in Gainesville, Florida, joined the GK–12 team. They participated briefly in some of the research projects
and shared in final presentations of the work to faculty, students, and other collaborators at UKZN. Then
everybody visited several public schools, where they shared some of the hands-on, inquiry-based lessons
they had developed together in Florida. All of the lessons related to ecosystem health and sustainability.
The visit to one of the schools, Mandini, was especially eye opening. SPICE Fellows and Teachers were
enthusiastically welcomed—which in South Africa includes boisterous song—and quickly inspired by the
juxtaposition of positive attitudes and conditions far more impoverished than what most SPICE participants
had previously experienced (or imagined). Soon thereafter, they established a sister-school project with a
middle school in Gainesville that provides a high proportion of students with free or reduced meals (i.e.,
the closest possible counterpart to Mandini in Gainesville). Over the next year, large boxes of classroom
supplies were collected from the Gainesville community and sent to Mandini, and a pen pal project
flourished between adolescent students, who exchanged personal descriptions of life in two very different,
yet very similar communities.

EXPLORING BIODIVERSITY IN FRENCH POLYNESIA

University of California (UC)–Berkeley
http://gk12calbio.berkeley.edu/

This international GK–12 effort was based on the island of Moorea, French Polynesia, where UC Berkeley has
an active field station: the Gump South Pacific Research Station. The station has a cooperative agreement
with the French Polynesian government “to document and protect the biological heritage of the islands.”
However, it is often difficult for scientists to communicate their knowledge to local communities, even more
so when there are linguistic and cultural hurdles to overcome. One of the key conditions of linking the GK–12
The project involved one or two GK-12 Fellows per year, in a manner similar to Exploring California Biodiversity, the primary GK–12 effort in California. Each Fellow spent an entire year in the school, working with Teachers and other educators in four classes at the primary partnering school, Ecole élémentaire de Paopao, in the Paopao community of Moorea, under the direction of Principal Mrs. Sylvie Juventin. A key element that made this partnership possible was that the island is sufficiently small to allow strong ties to be developed between U.S. graduate students and the schools. The educational system in French Polynesia follows the French model, with school mandatory between the ages of 5 and 16. Yet much of the population—especially the ethnic majority native Polynesians (78% of the population) —remains poorly educated.

The research focus was island biodiversity and ecology, divided into three units: (1) insect diversity; (2) plant diversity; and (3) marine biology. The primary goals were (1) to engage elementary school students in the process of science through studies of biodiversity and natural history collections and (2) to foster recognition and appreciation of science and the environment. Despite the island’s having abundant biological resources (especially in the marine realm), local biodiversity is not often emphasized in the French Polynesian science curriculum, weakening students’ appreciation for their natural environment. Indigenous Polynesian culture emphasizes the practicality of biodiversity, as a variety of plants and animals have been used for food, medicine, building materials, and tools for centuries. But the Western concept of science is not organic to the culture. As a result, scientific infrastructure is generally weak in the country, with little opportunity for students to pursue basic research. Those wanting to follow a career in science usually go abroad, often to France, once they reach university level.

For this effort, Fellows Brad Balukjian (’08 –’09) and Molly Wright (’09 –’10) were based at the Gump Station and taught weekly lessons in the local elementary school’s fifth-grade class (CM2 in the French educational system). Additional graduate students were involved, but for shorter periods. A series of over 20 lessons was designed by the Fellows from scratch. Each lesson plan was evaluated to fit the local education standards and requirements. Both observation- and hypothesis-based science were covered, with emphasis on discovery, a notion that is critical for this age group. Fellows also served as conduits between research being conducted at the field station and the local K–12 community. The elementary school students were brought to the station to observe research in progress and also visited the Musée de Tahiti et des Îles, the natural history museum on the neighboring island of Tahiti. Toward the end of the year, GK-12 Fellows gave seminars to local teachers about how to create similar projects of international collaboration.

Key highlights included the following: (1) As the culminating event of the project during the first year, the “Exposition des Sciences,” an elaborate science fair for the community, was hosted by students. This event was attended by such dignitaries as the French Polynesian Minister of Education, and it was covered by the local newspaper and TV station. (2) The GK–12 Fellows connected California urban schools with Moorea schools. Students wrote letters to each other and established an immensely satisfying cultural exchange, as the students realized how different (and similar) their lives and surroundings were in vastly different parts of the world.

Major outcomes included the following: (1) The project greatly enhanced global connectedness for the GK-12 Fellows, not only on-site in Moorea, but also in California. (Brad Balukjian and Molly Wright both participated in weekly meetings with California Fellows via Skype.) Balukjian and Wright are now fluent in French, have much improved teaching and communication skills, and have gained a deep appreciation of cultural differences; (2) The Fellows gained a better understanding of the local educational system and its
differences with the U.S. system; (3) The Fellows strengthened their ability to communicate and work in a multicultural setting; (4) The Fellows improved their understanding of local history and culture, particularly through collaboration with the Te Pu Atitia Cultural Center; (5) The project influenced local perceptions. Indeed, the local community heralds this effort as one of the most important in outreach and education that has ever been attempted by U.S. researchers in French Polynesia! Having heard about the project from newspaper articles and the Teachers themselves, the government offices in Papeete now want to expand the effort to the main island. They are willing to provide whatever support is needed from the French Polynesian community.

Challenges included (1) establishing the confidence of the community; (2) navigating the labyrinthine bureaucracy of the French educational system; (3) adapting lesson plans for teachers to use on their own; and (4) linking to activities in Berkeley. Currently being explored are ways of building this effort to become a sustainable enterprise that links the research at the field station with the local schools.

EXTREMPHILE RESEARCH AT THE UNIVERSITY OF NAIROBI AND IN KENYA’S GREAT RIFT VALLEY

University of Southern Maine
http://nanodiscoverylabs.org/index.php/maine.sciencecorps
Fellows in the Maine ScienceCorps project at the University of Southern Maine (USM) collaborated in international astrobiology research investigating microbes and bacteriophages of the extremely alkaline and hypersaline soda lake ecosystems of the Great Rift Valley. Research visits of GK–12 Fellows to Kenya began in 2008 and continued during 2009 and 2010 to establish the collaborative framework for long-term ongoing interactions between scientists at USM and the University of Nairobi (UoN). A total of five Fellows and one high school biotechnology Teacher traveled to Kenya.

Planning for this international research project began during 2007. The decision to apply for support for collaborative extremophile research in Kenya grew out of an existing collaboration between USM and NASA scientists and the knowledge that the soda lakes of East Africa include the most alkaline and hypersaline aquatic environments to be found anywhere on Earth. Through a NASA team already active in education and research in Kenya, the USM GK–12 project faculty and Fellows were connected with scientists at UoN in the Department of Geography and Environmental Studies. Of particular interest to the research team are the bacteriophages and viruses of the soda lakes. These organisms are the most abundant biological entities in most ecosystems, but are underexplored in extreme environments. It is expected that the interplay of these viruses and their hosts are critical in shaping nutrient cycles and driving microbial evolution in these unique halo-alkaline environments. Also among the soda lakes of Kenya are outstanding halo-alkaline hot-springs environments, such as the environment at Lake Bogoria, where thermophilic microbes and viruses can also be investigated.

After notification of the NSF award of supplemental international project funding, faculty research leaders at UoN and USM began to coordinate on obtaining the needed research permits and on scheduling an initial introductory meeting of the project leadership for January 2008 in Nairobi. This proved to be a challenging time to consider a new partnership, because the outcome of the national presidential election in Kenya during December 2007 was disputed and resulted in a time of unexpected violence and severe displacement of many people in some regions of the country. By April, advice from Kenyan colleagues

University of Southern Maine GK–12 Fellows taking samples from Lake Magadi in Kenya.
indicated that traveling to Kenya for research would be safe. In May and June, the PI and research staff from USM visited to lay the groundwork for the collaborative research and to plan for Fellows to begin research participation later in the year. During three years, Fellows and colleagues witnessed some important national transitions that culminated in the August 2010 referendum in which the Kenyan people approved a new constitution.

Setting up the requisite microbiology and molecular biology laboratory resources for the project at UoN came with the challenges of finding many needed supplies from a variety of local sources, but the project has been greatly enabled and made successful through generous sharing of laboratory space by Dr. Jacques Kabaru in the School of Biological Sciences and through the UoN research leader Dr. Francis Mwaura’s commitment to the project field research efforts and vast knowledge of the Great Rift Valley lakes and the surrounding communities.

Fieldwork at Kenya’s soda lakes, along with laboratory work in Nairobi and Maine, has resulted in the team isolating numerous microbes and viruses from the lakes. The USM–UoN team visited secondary schools and informal education centers located near the extremophile sampling sites and enhanced the microscopy resources at those sites. Light microscopes are necessary to directly view microbial populations, including those of the soda lakes. During the fieldwork, participants have greatly increased their awareness of the connections between scientific research and education, on the one hand, and the environmental conservation and development efforts of many Kenyan people, on the other. Local Maasai people near Lake Magadi, as well as the villagers and government officials near Lake Bogoria, have shown great interest in assisting in the research efforts and increasing understanding of the unique natural resources at the Rift Valley soda lakes, where they are actively engaged in building ecotourism initiatives to promote conservation while sustaining their cultural heritage. By staying at locally owned eco-lodges that are part of local ecotourism and conservation education initiatives, the USM and UoN team of researchers has become increasingly well acquainted with grassroots development efforts to which the research studies may positively contribute during the anticipated sustained partnership.

The USM–UoN collaborative research has resulted in the complete sequencing and structural analysis of several soda lake bacteriophages that are being studied as self-assembling nanostructures with potential nanomedicine applications. Recently, the USM investigators were awarded a Grand Challenges Exploration Phase 1 grant from the Bill and Melinda Gates Foundation for a proposal to continue working with Kenyan colleagues in developing a versatile soda lake bacteriophage-based vaccine platform for a prototypic multistage malaria vaccine.
<table>
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<tr>
<th>RESOURCES</th>
<th>Supports international collaborations and provides opportunities for students to conduct research abroad</th>
<th><a href="http://www.nsf.gov/div/index.jsp?div=OISE">http://www.nsf.gov/div/index.jsp?div=OISE</a></th>
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<tr>
<td>Asia Nano Forum</td>
<td>Network for sharing information and promoting collaborations around nanotechnology</td>
<td><a href="http://asia-anf.org">http://asia-anf.org</a></td>
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<td>India Report</td>
<td>Dr. Sonia Ortega’s GK-12 visit to India includes potential venues for partnerships</td>
<td><a href="http://www.gk12.org/files/2010/04/Ortega_India_Report.pdf">http://www.gk12.org/files/2010/04/Ortega_India_Report.pdf</a></td>
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<tr>
<td>Consortium for Affiliates for International Projects (CAIP)</td>
<td>Network of scientific and engineering societies’ activities in international dimensions of their disciplines</td>
<td><a href="http://www.aaas.org/projects/international/caip/">http://www.aaas.org/projects/international/caip/</a></td>
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<td>Community Research and Development Information Service (CORDIS) for Science, Research, and Development</td>
<td>Managed by publication office of European Union. The site contains information about the EU Seventh Framework</td>
<td><a href="http://cordis.europa.eu/guidance/welcome_en.html">http://cordis.europa.eu/guidance/welcome_en.html</a></td>
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<tr>
<td>Cosmos Education</td>
<td>International nonprofit organization dedicated to improving science education in developing countries</td>
<td><a href="http://www.cosmoseducation.org/">http://www.cosmoseducation.org/</a></td>
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<tr>
<td>Institute on International Education</td>
<td>Provides education and training to a diverse range of participants, sponsors, and donors</td>
<td><a href="http://www.iie.org/">http://www.iie.org/</a></td>
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<tr>
<td>Charles Darwin Foundation</td>
<td>Provides scientific research and technical information to support research in the Galápagos Islands</td>
<td><a href="http://www.darwinfoundation.org/english/pages/index.php">http://www.darwinfoundation.org/english/pages/index.php</a></td>
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<tr>
<td>The Fulbright Scholars Project</td>
<td>Offers U.S. faculty and professionals grants to teach and conduct research in many countries</td>
<td><a href="http://www.cies.org/us_scholars/">http://www.cies.org/us_scholars/</a></td>
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<tr>
<td>International Long Term Ecological Research</td>
<td>Global network of research sites located in ecosystems around the world</td>
<td><a href="http://iltternet.edu/">http://iltternet.edu/</a></td>
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<tr>
<td>Organization for Tropical Studies</td>
<td>Consortium of 63 universities to support research in the tropics</td>
<td><a href="http://ots.ac.cr">http://ots.ac.cr</a></td>
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<tr>
<td>Peace Corps: Coverdell World Wise Schools</td>
<td>Resources related to schools involved with Peace Corp volunteers around the world</td>
<td><a href="http://www.peacecorps.gov/wws/">http://www.peacecorps.gov/wws/</a></td>
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<tr>
<td>German Academic Exchange Project (Deutscher Akademischer Austausch Dienst, DAAD)</td>
<td>Awards grants to conduct research and sponsors visits to Germany</td>
<td><a href="https://www.daad.org">https://www.daad.org</a></td>
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<tr>
<td>Smithsonian Tropical Research Institute (STRI)</td>
<td>Located in Panama, STRI provides opportunities for conducting ecological studies in the tropics</td>
<td><a href="http://www.stri.si.edu/">http://www.stri.si.edu/</a></td>
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<tr>
<td>Singapore International Graduate Award (SINGA)</td>
<td>Supports PhD training in Singapore</td>
<td><a href="https://www.singa.a-star.edu.sg/">https://www.singa.a-star.edu.sg/</a></td>
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<td>Earthwatch Institute</td>
<td>Supports teachers who seek to join expeditions around the world</td>
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<td>Global Exchange Resources</td>
<td>Promotes improvements in elementary and middle school mathematics instruction</td>
<td><a href="http://www.globaledresources.com">http://www.globaledresources.com</a></td>
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<tr>
<td>Global Explorers</td>
<td>Nonprofit organization that organizes workshops for students and teachers</td>
<td><a href="http://www.globeexplorers.org/projects/group_travel/">http://www.globeexplorers.org/projects/group_travel/</a></td>
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<tr>
<td>GLOBE</td>
<td>Promotes and supports students, teachers, and scientists who wish to collaborate on inquiry-based investigations about Earth’s environment</td>
<td><a href="http://classic.globe.gov/">http://classic.globe.gov/</a></td>
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<tr>
<td>International Education and Resources Network (IEARN)</td>
<td>Global network that enables teachers and students around the world to use the Internet to collaborate on projects</td>
<td><a href="http://www.iearn.org/index.php?q=index.html">http://www.iearn.org/index.php?q=index.html</a></td>
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<tr>
<td>Japanese–U.S. Teacher Exchange Project for Education for Sustainable Development (ESD)</td>
<td>Supports U.S. teachers and administrations in traveling to Japan to learn about ESD and strengthen curricula in both countries</td>
<td><a href="http://www.iie.org/en/Projects/ESD">http://www.iie.org/en/Projects/ESD</a></td>
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MEASURING THE EFFECTIVENESS OF A PROJECT and evaluating its outcomes are important considerations in the design of any project, but here we focus on GK–12 projects. Evaluation is something that should be discussed and planned for from the very outset. What are the goals and objectives of the project? How should progress toward those goals be measured? What will achievement of the goals look like? It is important to know what success at the end will look like before beginning a project. Far too many people wait until the project nears completion before thinking about evaluating its impact. Don’t let this happen to your GK–12 project!

THE IMPORTANCE OF EVALUATION

The project leadership team (including the evaluator) should establish the goals and objectives of the project, decide what success looks like, and develop a method for measuring that success. Along the way, formative evaluation tools can be used to guide the leadership team as it progresses. At the end, summative evaluations can help to report on the progress achieved toward meeting those goals, as measured against clearly written objectives. This chapter will provide guidance in doing that.

The evaluation process serves four purposes (Chubin et al. 2011):

- It helps the project managers do what they are trying to do as well as possible. This is often called formative evaluation.
- It provides indicators showing that the project management team actually did what it set out to do. This is often called summative evaluation.
- It provides information aimed at a broader audience, which shows what was learned during the operation of the project.
- It provides information that allows others to adopt or adapt successful innovations, thus enabling the scaling and replication of successful project activities to a new project.

Oftentimes, an evaluation process is required by funding organizations. Different granting agencies have different expectations. Their expectations must align with the methods utilized in measuring success, and those methods must meet the agencies’ reporting requirements. The Government Performance and Results Act of 1993 requires federal agencies to report the accomplishments of funding recipients each year (National Science Foundation 2010, p. 4).

The best way to begin to design an evaluation for a GK–12 project is by starting with the end in mind. It is important to first establish clear goals (broad statements).
and objectives (specific skills and outcomes). The goals should be based upon what is to be achieved as a result of the project. For example, most GK–12 projects set out to improve (1) communication and teaching skills for graduate students; (2) STEM content knowledge and the use of inquiry-based teaching for teachers; and (3) interest in STEM careers and learning for K–12 students. Regardless of what you determine your endpoint(s) to be, you must decide on the evidence needed to monitor the progress being made (Wiggins 2005).

The project goals may involve K–12 students, graduate students, teachers, university faculty, the university culture itself, etc. (For more details and examples of impacts measured through the evaluation of various GK–12 projects, see Chapter 12.) The important point is that evaluation methods need to start with a clear vision of the objectives that will be developed to meet the goals. Moreover, that vision needs to be realistic. For example, it is highly unlikely that involving a graduate student in a science classroom for one day a week will help any school meet its “adequate yearly progress” goals of No Child Left Behind. Doing so might help toward making progress, but the goals need to be reasonable. They also need to address all of the participants in the project.

Once the goals are established, the objectives need to be clear and measurable. As projects progress, there is a careful line that must be walked between sticking to your original objectives and having the vision and flexibility to revise those objectives when appropriate. The key is in determining when it is appropriate. To simply abandon the original objective because it was not met is not a valid evaluative decision. However, narrowing the scope of your project once experience tells you that things aren’t working out according to the plan is a valid reason for further examination.

Once the goals and objectives are established and the evidence pertaining to those objectives is determined, the appropriate assessment tools can be designed.

The project evaluation needs to be carried out within the context of the overall goals. The terms evaluation and assessment are sometimes used interchangeably; in this section, however, we will use evaluation to refer to the process of determining the effectiveness of project activities rather than the effectiveness of individuals. The term assessment is frequently used for the process of ascertaining an individual’s gains in content knowledge and skills, often as measured by objective tests. By contrast, the term evaluation is not applied to individuals such as Fellows or Teachers, but is directed at the project as a whole.

**KEYS FOR SUCCESS: EVALUATION AND ASSESSMENT**

- Plan for evaluation and assessment from the very beginning of the project.
- Include someone who is familiar with evaluation and assessment on the project team. The university’s education department may be a good place to look.
- Develop a logic model that clearly outlines short-term and long-term measurable goals and objectives.
- Make sure that sufficient funding for evaluation is requested and made available.
- Identify specific individuals who are responsible for securing the necessary Institutional Review Board approval for all proposed evaluation and assessment.
- Ensure regular communication between the project management team and the evaluators.
- Be aware that teachers and students are constantly bombarded with various assessments and evaluations; be aware of evaluation/assessment fatigue.
- Use data from formative evaluations to guide decisions about potential changes in implementation strategies.
- Use data from summative evaluations to communicate project achievements.

**Getting Started**

The evaluation plan typically is given a rough form in the project proposal phase and is then fleshed out in specific detail once the project is funded. In some cases, the funder may not require an evaluation; however, evaluation can be a useful tool internally as the project is developed and executed. A well-designed evaluation can provide valuable data
The audience for the evaluation is an important consideration: Will the evaluation be primarily formative and directed to the project staff? How will the feedback between evaluator and project manager be handled? One method might be to write periodic mini-reports to the management team throughout the year. Some have found that informal emails and face-to-face communications work well.

The key here is to build a partnership among the project manager, the evaluator, and the funding agency or oversight entity. One way of describing this relationship is that the evaluator acts as a “critical friend” to both the project manager and the agency or group responsible for oversight of the project. Evaluation need not develop into an adversarial relationship; instead, ideally, evaluations “can contribute to the knowledge base to help understand what works and why” (National Science Foundation 2010, p. 13).

Choosing an Evaluator
An important question to ask is, Who will carry out the evaluation? You can often find individuals who are knowledgeable about project evaluation within the education department at most universities. GK–12 projects may have an internal evaluator who is a part of the project team or an external evaluator who is not directly involved with the project. The internal evaluator may be formally recognized in the funding proposal or may be a member of the project who is particularly interested in evaluation and who takes on this additional responsibility. The advantages of using an internal evaluator include lower evaluation costs and accessibility. The disadvantages are that the evaluation will likely suffer from a lack of impartiality and the funding agency may perceive the evaluation to be less credible than if it had been completed by an external evaluator. Some funders require the use of an external evaluator, although the definition of what constitutes “external” is sometimes not made explicit. A third scenario that can be used is to have both an internal and an external evaluator, with the external evaluator providing oversight on the necessary to communicate the impact of the project to an external audience. Such data will be essential if you wish to secure resources to sustain the project on a long-term basis. As a result, all project designs should include an appropriate evaluation plan.

The evaluation design team must answer these crucial questions:

- What is the purpose of the evaluation?
- Who will do the evaluation?
- What budget is available for the evaluation?
- What are the objectives and methods of the project as shown in the proposal?
- What evaluation questions are to be answered?
- What type of data will be gathered?
- How will the data analysis be carried out?
- How will the evaluation results be disseminated?

RECOMMENDATIONS

Consider the following questions related to funding agency requirements:

- What, if anything, does the funding agency require for the evaluation?
- Is an annual evaluation to be included as a section within the project's annual report?
- Does the funding agency require an external evaluator, or can the evaluator be a member of the management team?
- If the project is to receive funding, does the funding agency ask that the project manager respond to the evaluator’s comments?
- If there are nongovernmental or private-sector sponsors, what are their expectations and requirements for the evaluation?
- For multiyear projects, does the funding agency require a final report in addition to the annual report for the final year?
- How much funding is necessary to support the required reporting?
evaluation methods of the internal evaluator. Some GK–12 projects establish an evaluation advisory committee that usually consists of the project manager, the evaluator(s), individuals from various STEM disciplines, and academic administrators. The use of an advisory committee can provide a formal means of bringing project participants together to provide valuable feedback to the project managers and staff. The credibility of the evaluation process is enhanced as networking on STEM outreach activities between the advisory members is increased. The addition to the advisory committee of one or two research advisors (who have Fellows as advisees), as well as a participating Teacher or K–12 administrator, could provide valuable perspectives on the ongoing operation of the project, even if such a committee met only at critical times, such as a month or two before the start of the new school year and perhaps during the year in January or February. Another model that can be used is to have a graduate student in the university’s academic unit of education do the evaluation as part of his or her dissertation or thesis.

Understanding Project Goals and Objectives
What are the specific goals and objectives for the project? Often, projects have both primary and secondary goals, as well as specific objectives that help the project meet its stated goals. For example, a primary goal for a GK–12 project may be to improve the STEM content knowledge of K–12 teachers. However, because we believe that a teacher with a deeper understanding of STEM content is a better STEM teacher, a secondary goal may be to improve K–12 student understanding of STEM concepts. It is frequently useful to take the language in the project proposal and rewrite the goals so that they include implied secondary goals as well. Further, there must be a clear understanding of how proposed goals and activities match up—specifically, how the proposed activities will work toward meeting the goals.

It is useful to break out the main participant groups and to list the outcomes expected from each group. This information is not always obvious from the proposal. Thinking in terms of participant groups helps to organize the evaluation activities. In the case of GK–12 projects, participant groups would include, GK-12 Fellows, the Fellows’ research advisors, the project manager(s) and staff, the participating Teachers, K–12 administrators, and the K–12 students. Depending on the specific activities of the project, you may also want to look at how the project affects other things, such as Teacher or student participation in summer workshops organized and taught by the Fellows. Some projects may be involved with informal science activities at museums or other locations, and you might wish to consider the students who are involved as well as the staff of these institutions.

The evaluator should try to be sensitive to the effects of the project beyond the targeted participants. The activities of the Fellows may have an effect on teachers other than the participating Teachers who are formally signed up with the project. Also, parents and school administrators may be affected by the activities of the Fellows, and this effect may be something you wish to assess. Regardless of your evaluation’s primary focus, some attempt should be made to capture these “unanticipated consequences.” It is important to keep in mind that the two main purposes of the evaluation are to help the project manager and project staff be as effective as possible during implementation of the goals and objectives and to summarize the impact in a way that it can be communicated to the stakeholders and be disseminated more broadly to the STEM education and research communities. Some funding agencies recommend or even require a certain percentage of the funded amount to be used for evaluation, while others leave the amount designated for evaluation up to the discretion of the developers of the proposal. The depth and focus of the evaluation will be determined not only by the expectations of the funding agency and needs of the project staff, but also by the project evaluation budget.

THE EVALUATION QUESTIONS
The idea is to use evaluation questions to establish a chain that links expected outcomes with project activities, or processes, as they affect specific participant groups. It is useful to distinguish between process evaluation questions, such as “How well are the processes of the project working?” and outcome evaluation questions, such as “What is the impact on the participants of project activities?” A process question that might be asked is, for example, “What
is the evidence that Fellows are present in classrooms for the required number of hours per week?” An outcome question might be “What is the evidence that the presence of the Fellows in the classroom is increasing student interest in pursuing science careers?” Process and outcome questions can be answered by qualitative and quantitative measures. A clear understanding of the purpose of the evaluation is critical in developing the questions. (See Radhakrishna and Realdo 2009, Langemyer 2008, and National Science Foundation 2010, for additional discussion of the purposes of evaluation.)

Participant Groups
As mentioned earlier, viewing your GK–12 project in terms of participant groups often helps the person doing the evaluation gain a global view of the activities of the project. An understanding of the people who are in the participant groups will help the evaluator put data gathered from project activities in context. Stakeholders and participants differ. Participants are a part of the activity of the project, whereas stakeholders have an interest in the project but may not be directly involved with its activities. Funders involved with the project have a stake in the project but do not participate directly. Members of the participant groups may be directly targeted by the project for certain outcomes, or they may be associated with the project activities in a more indirect manner.

The six principal participant groups for a GK–12 project are GK-12 Fellows, the Fellows’ research advisors, the project manager(s) and staff, the participating Teachers, K–12 administrators, and the K–12 students. Depending on the project, the evaluator might identify other important participants.

Consider the following evaluation questions in light of the proposed goals of the GK–12 project:

- What measurements might be available to answer evaluation questions?
- Will the answer be supported by qualitative evidence, quantitative evidence, or both?
- What will the trade-off be between the costs in time and money of answering a given evaluation question and the value of the answer to the overall evaluation?
- What are the issues that come into play in seeking certain types of information from schools on student academic performance?

that reflect the specific activities undertaken.

It is helpful for the evaluator to take a few minutes to think about the demographics and other characteristics of the people in each of these participant groups and ask these questions:

About the GK–12 Fellows:
- Are they undergraduate or graduate students?
- What are their disciplines and disciplinary areas?
- What is the diversity of the Fellows’ backgrounds?
- Are they MS or PhD students?
- What are their career intentions after graduation?
- How old are they?
- Have they had previous experience in K–12 schools?
- Are any of their parents teachers?

About the GK–12 Teachers:
- What has been their past experience with the university?
- What grade levels do they teach?
- How many years have they taught?
- Are they teaching science full time in the schools or splitting their time with other subject areas?
- What are the Teachers’ male–female ratios?
- What is the minority group representation in this set of Teachers?
- What is their comfort level with science?
- What type of science background do they have?
About the research advisors:
- Have they had any previous experience with STEM outreach?
- What stages in their careers are they?
- Are they tenured?
- What is the lab environment like?
- How do they relate to their graduate students?
- How do they view STEM outreach activities?
- What is their general research agenda?

About the project managers:
- What is their background with STEM outreach?
- Are their positions career positions? How long have they been in their current positions?
- What professional activities in their respective disciplines have they participated in in terms of research topics, professional organizations, and publications?
- What is their history with the project? (How did they become involved?)
- What is their background with STEM outreach?

Perhaps the most challenging participant group when it comes to evaluation and assessment is the K–12 student group. There are more of them and, more importantly, schools may be reluctant to share very much information beyond state and federal reporting measures. There are also privacy issues for minors, and taking part in the evaluation will require parental permission. Basic demographic information should be available online. Such information will vary state by state, so check with the school guidance counselor or building principal for advice on where to find this publicly accessible information.

A visit to the classroom and an informal interview with GK–12 Teachers after the project starts up may provide more information on the students, such as the number of English language learners, the ethnic backgrounds of the students, a general view of the students’ academic performance, and the number of special-needs children in classroom visited.

Project Activities
In addition to the participants and the participant groups, the project activities are a central focus of the evaluation effort. A useful exercise is to create a matrix identifying activities of the project and which participants will be engaged in and/or affected by each activity. Try to be complete with the list and capture the effects on both targeted populations and participants who are not formally mentioned in the proposal but are likely to have an important impact on the success of the project. For example, if your project includes STEM graduate students, it is likely that the attitudes of the Fellows’ research advisors toward STEM outreach activities versus the value of lab time will be an important factor for advisees who participate in the project, as well as in the recruitment of new GK-12 Fellow participants in multiyear projects. The views of the advisors will also be important for projects that expect changes in the nature of STEM graduate education. As the project develops, evaluators will become better sensitized to see unanticipated consequences in addition to expected outcomes.

DATA AND DATA SOURCES
Multiyear projects designed around the NSF GK–12 approach have typically produced large quantities of qualitative and quantitative data. The selection of data sources and data-gathering methods to be used will involve a trade-off between the time and money available and the relative utility of the data collected to provide answers to the evaluation questions. Data-gathering approaches and instruments will differ for the members of the participating groups. For example, the questions, tone, and feel of the Fellows’ survey will not be the same as those same qualities in the survey used for the advisors. Self-reports produced by the participants in response to surveys and interviews and interpreted by the evaluator become a prime source of information. The surveys and interviews may include Likert-scale questionnaires, free-response questions, and/or open-ended interviews without preset questions or topics. (See Appendix 9.1 for samples of GK–12 survey instruments. Also, an introduction to constructing questions of various types can be found on the SuperSurvey website at http://knowledge-base.supersurvey.com/survey-questions.htm.)
Focus groups may work well for some projects. The information given by one group can be compared with that given by another group to provide a confirmation of an effect. For example, you may wish to ask if GK-12 Fellows see an increase in their ability to present talks at meetings as a result of participating in the project, while also asking advisors and Teachers how they view the GK-12 Fellows' growth in this area. Fellows' logs and periodic reports are also a good source of qualitative data.

Other data-gathering methods can be useful as well. Observations of project meetings, of the Fellows in the classroom, and of other important project activities can produce valuable information. In addition, artifact analysis is a technique that looks at physical and online products produced by the project, such as hands-on lab sheets developed by Fellows, hands-on lab apparatus, summer camp curriculum materials, and summer teachers' workshop presentations developed and delivered by the Fellows. In this case, the evaluator looks closely at one or two examples of these objects and a one-page analysis summary is prepared. Comparisons can then be made with similar Fellow-developed artifacts from STEM outreach activities locally or at other institutions.

The NSF GK–12 project locator at http://www.gk12.org/ provides links to other projects, on whose websites you can find a variety of products developed by Fellows and Teachers, as well as a variety of resources. The project web pages that are created as the project develops are another important "artifact" that can be examined in detail and used to benchmark against web pages created by comparable projects.

Obtaining data on the K–12 students can be problematic, as much of the information may be held closely by the school or may take an unreasonable amount of time and effort to obtain. With the proper prior approval, however, it is possible to administer pre and post instruments to assess student learning or changes in attitudes as a result of a GK–12 project. Changes in student attitudes toward science, scientists, and science careers can be measured by various instruments. Focus groups of students exploring attitudes toward science and science careers as a result of the presence of a Fellow in the classroom can be useful sources of information related to the impact of a project, as can observational data in the classroom. Spillane (2004) reports on GK-12 Fellows in the classroom and the effect of role models.

Institutional Review Board regulations are more stringent for minors and need to be taken into account, particularly when one is doing interviews or focus groups with children. Coordination with the school principal, as well as permission of the classroom teacher, is needed. Don't forget to back up your data on a regular basis and to use a means of maintaining the confidentiality of what has been shared with you. Individual responses to surveys and other instruments should be immediately coded by the evaluator and identifying information replaced by the code for each individual. Information in direct quotes that are used in the evaluation report needs to be edited to remove identifying information, such as a person's name.

Data Analysis, Reporting, and Dissemination

You will most likely have both quantitative data and qualitative data. The analysis of quantitative data will follow whatever standard techniques you are comfortable with. Attention should be given in analyzing Likert-scale items. The responses to an individual question on a five-point scale produces data that are termed ordinal, and a simple mean will not reveal much about the meaning of the data. A simple count of responses for each category, expressed as a percentage of total responses for that category, will result in more meaningful interpretation (Clason and Dormody 1994). A search of the Internet will uncover many useful documents on constructing Likert-type questions and analyzing the results.

Narrative, or qualitative, data presents a challenge because of the volume of data that is produced. Grounded Theory is one useful qualitative data analysis method that is simple, lends itself well to using multiple text files, and can be easily adapted to the analysis of qualitative evaluation data. Grounded Theory has been used quite successfully in health care research, particularly nursing. A good introduction to Grounded Theory is found in Strauss and Corbin (1991). The Grounded Theory method revolves around looking for repeated themes in the narrative and grouping examples that illustrate those themes by copying brief relevant passages. The material can be taken from free-response...
questions on surveys, interview notes (including quotes), emails, fellow or teacher reports, etc. The approach works well with electronic files, although it is important to maintain a file with backups of the original data before you start cutting and pasting to build evidence for the themes that are relevant to answering the evaluation questions. These organized narrative data also provide a rich source for quotes and “nuggets” that can be used to communicate project successes and learning to a wider audience.

“I am sure that no traveler seeing things through author spectacles can see them as they are.”
—Harriet Martineau, First female sociologist

SITE VISITS
GK–12 evaluation is a people-focused activity and is enhanced when face-to-face contact is maximized. Periodic site visits by the evaluator should be built into your evaluation plan and into the project’s evaluation budget. Site visits early in the project are important and help put faces to names. Initial interviews with participants can be used to explain what the purpose of the evaluation is and to develop a sense of trust. Later interviews can explore more topics in depth.

A team from the NSF GK-12 Program visits a middle school marine science classroom that partners with the Virginia Institute of Marine Science’s GK-12 project.

The site visit is also an opportunity to carry out observations in classrooms, to attend project meetings, or to be a part of other special activities, such as Fellow-led teacher workshops or summer camps. This is also a time when you might schedule meetings with research advisors and have a chance to visit their labs to see where the Fellows work. A visit to the project manager’s department will give the evaluator some idea of the university environment. Meeting the building administrators of the participating schools and establishing a good working relationship is critical to the success of your evaluation efforts. The evaluator also may wish to talk with district-level school administrators to get their views about the project. During the site visit, the evaluator will have an opportunity to see firsthand the lessons, lab equipment, and facilities that are being used. The site visit does add overhead in terms of time and expenses, but these visits can be very useful to the evaluator because they provide a deeper understanding of the context in which project activities are being carried out.

As you consider all of the ideas presented in this chapter, the most important thing is to plan adequately for evaluation from the beginning. Sometimes evaluation is seen as a burden, something you have to do that takes time and resources away from your project activities. But in reality, a good evaluation plan can allow you to focus your resources in a way that maximizes your impact. Evaluation and assessment is a bit of an “art,” and a good evaluation team and evaluation plan can help your GK–12 project stay focused and operate smoothly. In sum, good evaluation can save the project both time and money.


COMMUNICATION IS KEY TO THE SUCCESS OF ANY PROJECT. This chapter addresses means of disseminating project goals, activities, and successes to a broader audience. No matter how good a project is, if relevant stakeholders don’t know about its positive impacts, there is little chance that it can be sustained. As in any situation, it is necessary to understand the motivations of stakeholders, both current and potential. First, we review materials and documents that are useful for the dissemination of project activities. Next, we explore the variety of stakeholders that should be considered in crafting a plan for dissemination. Several examples of successful dissemination techniques are presented throughout the chapter.

MATERIALS FOR DISSEMINATION
Developing materials tailored to specific audiences is important for expanding and sustaining a project. Materials should include a concise description of the project’s (1) goals, (2) initiatives, (3) partners, (4) activities, (5) scientific focus, and (6) target audiences. Having this information clearly articulated in advance will aid the development of further materials for dissemination. Materials can be developed by project leaders and through the creative input of Fellows, Teachers, and even K–12 students. Materials can be a simple handout, a CD discussing project materials, or a business card to reference the project’s website. A logo can help brand a project and provide visibility on all dissemination items. A university logo can be included as well, but clearance may need to be obtained from the university’s press office. A discussion of potential dissemination resources and materials follows.

Websites/Electronic Media
One of the most important means of communicating with a geographically dispersed, diverse audience is through a website or other electronic media. A website serves as the first point of contact for information on a project’s activities, resources, and events. Minimally, the site should contain all six types of information listed in the previous paragraph, plus contact information for all participants. The site should be accessible to participants as well as the general public. A private, password-protected portal for Fellows, Teachers, or other project personnel can be added to a website for information that is for internal use only (e.g., information on salaries, benefits, and regulations). A wiki, or blogging website, can also be used as a way for participants to view, edit, or comment on project materials (e.g., presentations, posters, and instructional plans) A well-designed website can be one of the best ways of interfacing with the public and
reflects how a project is viewed from the outside. Therefore, it should be considered a high priority for project dissemination, and it needs to be updated on a regular basis. (See “RESOURCES” at the end of the chapter.)

Pamphlets, Brochures, Newsletters, and Flyers
Pamphlets and brochures can be created to advertise project events, recruiting information, field trips, and accomplishments. These materials are easily distributed at schools, on campus, or at public events. The benefit of pamphlets is that the information in them can be changed, updated, and reprinted with ease and little financial investment. Pamphlets can also be created for specific purposes, such as recruiting, describing project goals, or advertising upcoming events. This format allows a project to target a specific audience (e.g., prospective Fellows, Teachers, school district administrators, and parents) without overwhelming them with extraneous information. (See the sample flyer from a GK–12 project on the following page.)

A newsletter is a good way of periodically distributing information that requires a longer format. Possible items to talk about are Fellows, research, school partner highlights, specific project outcomes, upcoming presentations at conferences, and a “Where Are They Now?” column for project alumni. A benefit of newsletters is that they can be distributed in print or electronic format: The latter provides an inexpensive way to reach a large audience. The distribution list can include project alumni, faculty, current or potential funders, parents, Teachers, public relations or development officers, and community business owners.

Posters
Posters that outline project goals and activities are a great way to draw attention to accomplishments. Posters can be presented at technical and educational conferences, university events, PTA meetings, school or university science days, orientations, and even legislative sessions. Be sure to give recognition to supporters by including logos and/or references in conspicuous places. Posters can focus on Fellows’ research, classroom activities, field projects, or data that K–12 students collect. Fellows may want to create posters that appeal to a general audience by highlighting their research in ways that are meaningful or easily conveyed to a group of nonscientists.

Abstracts, Articles, and Presentations (Scientific and Educational)
Over the last decade, GK–12 partners, together with university faculty, Fellows, and Teachers, have published hundreds of scientific and educational articles in peer-reviewed journals and conference proceedings. The unique partnerships and outcomes of the GK–12 projects provide an interesting perspective for traditional research- and education-focused journals. A project can publish the unique elements of a partnership, creative lesson plans, or pedagogical methods in both scientific and education journals. There are several venues to highlight your novel curriculum, assessment, and pedagogical approaches to science and engineering education (e.g., the Journal of Geoscience Education, American Biology Teacher, Chemical Education Reviews, and the Journal of Engineering Education, among others). Take advantage of opportunities to give presentations in the education session of scientific meetings (e.g., the K–12 session of the American Institute of Chemical Engineering annual meeting). In that setting, both educational
and scientific advancements can be discussed in an open forum. Also, consider additional dissemination by participating in STEM education associations such as the American Society of Engineering Education, National Association of Biology Teachers, National Science Teachers of America, and others.

Field Trips and Experiments (Real and Virtual)
Although not technically forms of dissemination, field trips, campus visits, and lab tours are an effective way to expose K–12 students and Teachers to scientific research and scientific professionals in an authentic setting. Such activities help strengthen connections between the university and K–12 communities, as well as offering the opportunity to involve students in longer term research projects and exposing faculty and other graduate students to the benefits of the GK–12 project.

If a lab tour for nonparticipants is not possible, consider filming the graduate students giving a tour of their lab or demonstrating part of their experimental procedure. Virtual tours could also be given, via Skype or other video connection facilities. These have the benefit of exposing K–12 students to a university laboratory setting and giving them the opportunity to compare and contrast different experimental environments (e.g., different lab techniques, the clean room, and microscopy labs). This form of virtual field trips can also be used for environments that require off-site testing (e.g., mountainous or underwater regions) and is beneficial in cases where the experimental process uses biological or hazardous materials or when the experiment needs to be conducted in a restricted-access area. Note that a DVD can be made and disseminated to schools or local news media, thereby providing a mechanism for wider distribution.

Lesson Plans, Activities, and Descriptions of Experiments
It is helpful to have a compilation of the activities, lessons, or experimental procedures typed, formatted, and combined in a deliverable format. Collaborating with Teachers on the format, types of information to include, and compliance with standards is important for creating a sustainable repository of educational resources. One example is a binder of procedures or lesson plans to be used as a reference in a school laboratory. Not only can Fellows use it to reference activities, but Teachers at the school can also access it when the Fellows are not present. Links to this information should be included on the project’s website. Teachers can augment the ideas or use them to enhance their own curriculum. The project could also create CDs of the formatted documents and distribute them at partner schools, within the university, and at education and research conferences. Having the activities typed, formatted, edited, and readily available in hard or soft format will assist in disseminating and broadening the project’s activities. Lesson plans should also be distributed on a project’s
website and/or the partner institution’s website. For national dissemination, consider submitting your lesson plans to the National Science Digital Library portals, such as TeachEngineering. Fellows can also volunteer to review lesson plans as an exercise to strengthen their writing and reviewing skills.

**Business Cards**
As with any professional entity, having a business card with information about the project can be an effective dissemination tool. Elements of the card could include a logo, a phone number, a webpage, an email address, and some basic information about your project. Consider making cards for Fellows and other team members. Louisiana Tech University, for example, created individualized cards for each Fellow that included the Fellow’s school email address, advisor’s name, and five bulleted points about the Fellow’s research (see below). The cards not only increased exposure of the project, but also highlighted the Fellows’ research efforts and their advisor’s commitment to the project. The information on the cards allows for widespread distribution at both educational and scientific events.

**Press Releases**
A press release can be an effective way to advertise a specific event or activity of your project that may be of interest to a broad audience. The press release can be disseminated to various news outlets, including campus and local newspapers, radio shows, and television news stations. The timing of the press release is particularly important. Most news agencies prefer advance notice of a week or more and like to publish articles based on specific events, discoveries, or occurrences in the community. Develop a relationship with media personnel by stopping by their offices, speaking with editors, or inviting them to events. Contact the journalists that cover science and education issues; their names can usually be found on media websites or via a phone call to the local news office. Make sure to follow your university’s policy on news submissions, as some universities require that clearance be granted before publication. (The media as a stakeholder is discussed later in the chapter.)

The university’s media relations department should be contacted as soon as it becomes apparent that there will be an event. Request help in developing the release, because there may be a required format. Alternatively, GK–12 participants can write the release and send it to media personnel to edit and distribute. A well-written press release includes an attention-grabbing title, a description, the time and location of the event, and complete contact information for a point person. An example of a press release from the University of Utah’s WEST GK–12 project follows.

**Annual Reports**
An often overlooked source of information for dissemination is an organization’s annual project report. Many funding agencies, including NSF, require an annual update of project activities and accomplishments. Some projects publish their reports on their website, while others consider the information proprietary. Well-written sections of project reports can be excerpted into other dissemination documents, and vice versa, making the most of the effort put into them. When writing a report for an agency, a university, or a community audience, consider items prepared for (and from) your dissemination resources.

**STAKEHOLDERS**
Communicating the success of projects to a variety of stakeholders is crucial to maintaining long-term relationships and support. Each stakeholder comes with a different set of values and priorities that need to be taken into account when you are presenting them with the project’s accomplishments and potential. Some primary stakeholders and potential means of communication to them are discussed next.
**Wetland Provides Unique Learning Opportunity for Escalante Elementary Students**

Teachers from Escalante Elementary have teamed up with scientists from the Dept. of Wildlife Resources and the University of Utah's WEST (http://www.earth.utah.edu/west) project to provide a unique conservation and education opportunity for students. A threatened Utah native fish, the least chub, will be introduced into the recently constructed wetlands at Escalante Elementary School. The least chub is a small fish native to the Bonneville Basin. Its numbers have declined severely, due largely to the introduction of nonnative fishes and loss of habitat. Currently, it occurs in a few springs and streams in western Utah. This project will provide students with a rare opportunity to become directly involved in the conservation of a native Utah fish and improve the quality of their school wetland while applying core science concepts at all levels.

The wetland itself is the result of a $100,000 Ford Motor Company–National Geographic “Radical Renovation” grant to improve school grounds. The water comes from a natural spring, which had been flooding the school's playing fields every year. Now, spring water is diverted to two artificial ponds, which are connected by a small stream. In addition, a native garden was constructed and filled with many plants native to Utah. Ever since their completion in June 2005, the wetland and native garden have served as an outdoor science classroom and a source of pride for Escalante students. Instead of reading about wetlands, students can make observations and run experiments in their own schoolyard. Students have designed and carried out projects comparing the water quality of their wetland with that of the Jordan River, monitored pollution indicators, identified macro-invertebrate species, and identified adaptations to aquatic life. The addition of a threatened native fish species to the wetland will not only help balance the wetland ecosystem, but also give students a chance to help conserve a threatened Utah fish.

The introduction of the fish to the wetland will occur on November 14 at 1:00 P.M. The wetland is located in the NE quadrant of the Escalante Elementary schoolyard.

WEST (Water, the Environment, Science and Teaching) is a National Science Foundation GK–12 project that provides science, technology, engineering, and math graduate students with support to work with K–12 Teachers and students throughout the school year.

For more information, contact John Doe at johndoe@email.com

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**Graduate Students**

Graduate students will likely be the primary participants in a GK–12 project. With the demands of course work and research, it is extremely important that students understand the value of participating in such a project and how doing so will help them achieve their academic and career goals. If the project has low visibility or is perceived as something that will be detrimental to their success as students, it is unlikely that the best candidates will be interested in participating.

Some ways to communicate the benefits of participating in a GK–12 project are by giving presentations or distributing informational materials at student orientations, recruiting events, and departmental seminars. Encourage students who are currently in the project to share their experiences with their graduate student peers, departmental faculty, and colleagues at professional meetings.

**Faculty**

Faculty need to know how the project benefits their graduate students, how the students' time away from research is being spent, and how the experience is preparing the graduate students to be better science communicators, better teachers, and better researchers. In essence, they need to know that the experience will help the graduate student to be successful beyond graduate school. The time spent in GK–12 activities is complementary to the time spent in a lab or writing papers. It broadens graduate students’ education and training.

One way to communicate this information to faculty is by giving a project presentation as a departmental seminar. Such a seminar must highlight how the project fits in with department goals and benefits both the academic and overall professional development of the participants. Letters highlighting the GK-12 Fellows’ activities can be sent to their
research advisors to make them aware of the impact their students are having on the K–12 community and on their peers. Invite faculty to attend or participate in your K–12 project’s seminars and activities or to serve on the project’s steering committee. Suggest that advisors and students coauthor a paper on their research and how they disseminated their work to the K–12 students or the public at large with the help of the GK–12 project.

**Institutional or University Administrators**

Ultimately, for a GK–12 project to be sustained, it has to have the support of the institution’s administrators. Administrators should know how the project is helping the institution meet its mission and goals. Keep administrators informed on how the Fellows, faculty, and departments are benefiting from the project and how it is aiding in recruitment and retention efforts. For public institutions, note how the project might be perceived positively by the legislature; for private institutions, observe how the project might be perceived positively by their governing boards.

Provide administrators with a two-page brief of the project and its impacts on students, faculty, and departments. Highlight any community connections that might affect the recruitment pipeline. Invite administrators to attend events that feature the project’s Fellows and K–12 students working and learning together. For example, the University of Utah’s “Think Globally, Learn Locally” GK–12 project hosted a Climate Science Forum on campus at which middle school students had the opportunity to teach faculty and graduate students about the carbon cycle and climate change. It was a terrific way to reverse the roles of faculty and K–12 students and made a lasting impact on everyone involved. Several deans, professors, graduate and undergraduate students, and the vice president of research attended the event.

**K–12 Community (Principals, District Professionals, Teachers, Parents, Students)**

Educators and administrators are facing increasing pressure to cover larger amounts of material with constantly dwindling resources. They need to be reassured that participating in the GK–12 project will be a valuable investment of their time. One of the most critical aspects of communicating a project’s success is letting the school administrators know about the value added by the project. A face-to-face meeting is highly recommended, and administrators should be invited to attend activities, field trips, and other project events. Informational flyers that address the goals of the project, time commitment of Teachers, benefits to students, types of services being offered, and alignment with curriculum standards and requirements can also be distributed to administrators and potential teaching partners. In addition, attending school board and PTA meetings increases awareness, if not support, by parents and the community.

**Peers**

Peer scientists are one of the most important target groups to which to convey the importance of GK–12 activities. Although not all scientists may be able to engage in K–12 education and outreach activities, if they come to appreciate the value of such efforts, they will be more willing to support the efforts in various ways. One way to inform peers of the value of a GK–12 project is to give presentations at professional meetings in technical sessions. Although several educational sessions are often offered at professional meetings, presenters typically end up speaking to those who are already engaged in K–12 outreach (i.e., they wind up “preaching to the choir”). If one can present the GK–12 project in such a way that it aligns with the content of a specific session, then there is a greater chance of expanding the audience. For example, one GK–12 project created a field experience for K–12 students that paralleled an ongoing selenium study of a local lake. Over the course of two years, university faculty and members of the State Department of Environmental Quality brought more than 2,000 children on a dinner-cruise boat converted into a makeshift research vessel to collect water samples, create density profiles, and analyze contaminants in the lake. Real data were collected by
the students and presented at the annual meeting of the American Geophysical Union in a technical session on saline lakes.

Political and Other Community Leaders
Informing political and community leaders about GK–12 activities is especially important for sustainability at the institutional level. These leaders have input on policies and directives that largely determine where resources will be focused. They are often well connected with business leaders and other potentially helpful community organizations. Most political leaders have an open-door policy when it comes to meeting with an organization and, if given enough advanced notice, may also be willing to promote your activities by attending GK–12 events that will benefit their political career. When they do attend, make sure that the media are there to cover the event. This will help you develop a relationship with your community leaders and open avenues of support as you work to sustain your project. One example is a Congresswoman’s visit to a GK–12 classroom and the associated press release (see below). Another is a GK–12 project’s work to develop a wetland on school grounds and then partner with the Department of Natural Resources (DNR) to introduce an endangered native fish into the wetland pond. The event was a public relations boon for the project, the DNR, the school district, and the politician who presided over the “grand opening” of the wetland. Make sure to give some of the dissemination materials suggested in this chapter to the political or community leaders attending your event.

Development Officers and Funding Agencies
Development officers at universities should be aware of project activities; they can often help connect with potential donors. Communicating with campus development officers also helps them do their job by providing a project to highlight when donors are solicited. The key to connecting with any funding agency is to make a case for how the goals of a particular project align with the funding agency’s mission. It may be helpful to write a “case statement” that outlines the fundamental concepts of the project, the operational budget, goals, and findings. Keep the statement as brief as possible (two pages or less), and tailor it to each individual agency’s mission and goals. Also, provide the funding agencies with any media or news items about your project. This will help build a relationship between your project and the potential funding agency.

Community Organizations
Work with community organizations (Girl Scouts, church groups, historical societies, etc.) to raise awareness about the project among nontraditional groups. Often, these organizations involve a diverse

Rep. Schakowsky Visits Northwestern University–ETHS Science Projects

OCTOBER 28, 2010

EVANSTON, IL. Congresswoman Jan Schakowsky recently visited Evanston Township High School to learn more about a new collaboration between ETHS and Northwestern University in which two Northwestern University astronomy graduate students, Benjamin Farr and Jason Hwang, are integrating their cutting-edge research into the science curricula at Evanston Township High School as “resident scientists.”

They are part of a new five-year project that puts graduate students in K–12 classrooms and trains them in communicating their complex research to people of all ages. The project, called “Reach for the Stars: Computational Models for Teaching and Learning in Physics, Astronomy and Computer Science,” pairs each doctoral student with an area science Teacher. The National Science Foundation (NSF) awarded this $2.7 million Graduate STEM Fellows in K–12 Education (GK–12) grant to Northwestern’s Center for Interdisciplinary Exploration and Research in Astrophysics (CIERA).

Five other graduate students from Northwestern’s science, technology, engineering, and math doctoral projects are resident scientists this year in other local schools. At ETHS, Farr is in the astronomy classroom of Gion Matthias Schelbert and Hwang is working with Dan DuBrow in physics. Each team will work closely all school year to develop lesson plans for the classroom that integrate computational thinking and scientific inquiry-based learning.

More information can be found at http://gk12.ciera.northwestern.edu/

SOURCE: NORTHWESTERN UNIVERSITY PRESS RELEASE
cross section of society that may not have access to quality science education. Also, use the opportunity to learn from these groups, since they bring with them a different perspective and understanding of science. For example, one GK–12 project has been working on an after-school project in which discoveries and research about life on Mars are shared with refugee youths in the school who, in turn, share their perspectives of habitable environments from their respective homelands. Both the Fellows and the youths benefit and learn from each other.

**Media**

Use the media to help inform all stakeholders. Keep campus media relations personnel aware of activities, send notices of events in advance, and include contact information on the project. Ask them to write a press release about an activity associated with the project—or write or record one (as a podcast) and send it to them. Media relations personnel should be interested in university and community activities because it is their job to keep their readers and listeners apprised of campus events. Request help from the partnering school district's media department as well. For big events, contact local news organizations by phone or email. Most newspapers and TV stations have a “report breaking news” or “suggest a news story” hotline or website. The more in advance the notice is given, the more likely coverage will be provided. Local radio stations are often interested in airing information about events and unique partnerships. Consider teaming up with campus newspapers and journalism students to produce stories about the project. One GK–12 project developed a partnership with the communications department on campus and partnered a journalism student with each Fellow. The Fellows benefited by learning how to communicate their research to the news media, while the journalism students benefited by gaining experience in science writing and building their portfolios. The GK–12 project as a whole benefited through the various press releases, blog postings, and mass-media articles that were produced via the partnership.

**RECOMMENDATIONS**

- Use materials and websites that are well written, professional looking, and regularly updated to communicate about your project.
- Always have materials prepared and handy.
- Initially, create two to three documents to disseminate, but continue to develop other materials.
- Talk about the project whenever and wherever possible. Don’t limit presentations to educational forums.
- Keep faculty involved in the project, even in minor ways, such as by sending them an update of activities or inviting them to a seminar.
- Prepare a project briefing or “case statement” that highlights the goals and benefits of the project; make sure to include a few colorful photos. Distribute the material to administrators, faculty, community leaders, funding organizations, and any other group that may share similar goals.
- Use all available avenues (student and faculty participants, campus and district media relations personnel, campus journalism students, development officers) to publicize your project.
- Reach out to nontraditional groups. They may provide support and can frequently offer unique perspectives.
- Do not be afraid to go to the top with your message. University administrators and community leaders will typically welcome information about successful and unique partnerships.
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<td>Emory annual report</td>
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### RESOURCES (CONTINUED)

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</tr>
</thead>
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<tr>
<td>Graduate student interviews</td>
<td><a href="http://peer.tamu.edu/NSFPages/NSF_Interviews.asp">http://peer.tamu.edu/NSFPages/NSF_Interviews.asp</a></td>
<td>Interviews of GK–12 Fellows about their research</td>
</tr>
<tr>
<td>Science education organizations</td>
<td><a href="http://www.ncsu.edu/imse/highres/2/organizations.htm">http://www.ncsu.edu/imse/highres/2/organizations.htm</a></td>
<td>List compiled by North Carolina State U</td>
</tr>
<tr>
<td>Science education journals</td>
<td><a href="http://homepages.wmich.edu/~rudged/journals.html">http://homepages.wmich.edu/~rudged/journals.html</a></td>
<td>List compiled by Western Michigan</td>
</tr>
</tbody>
</table>
SUSTAINABILITY AND SOURCES OF FUNDING

Doug Levey, Vikram Kapila, Pat Marsteller, and Ailene Altman Mitchell

CHAPTER HIGHLIGHTS

- Sustainability planning begins when the project is conceived.
- Successful projects require sustained leadership from the university and school administration, however, plan for transitions.
- Ongoing communication among all stakeholders creates a sense of community and shared responsibility.
- Building an infrastructure to prepare Fellows for teaching, communicating with the public, and outreach to students and Teachers can allow projects to continue when initial funding ends.
- Projects that are flexible and responsive to university needs, school district requirements, and Teacher and Fellow time are more likely to be sustainable.
- Sustainable projects honor and recognize the contributions of all and develop a culture of shared responsibility.
- Sustainability requires communicating success to all partners.
- Sustainability requires buy-in and investment.
- Funding exists to begin new projects or continue existing ones.

SUSTAINING A PROJECT beyond a grant funding cycle is perhaps the biggest priority for anyone who has invested the time, energy, and resources to build a university–K-12 partnership. However, building a sustainable partnership is a major challenge. Many great projects are stymied by leadership changes, institutional priorities, school district shifts in organization and curricula, and the inadequate incentives for faculty and teachers to invest in a transformative change of teaching and curricula; all such hurdles must be anticipated.

In this chapter, we highlight ways to plan for sustainability from the outset. We discuss types of leadership teams and how to plan for transitions in leadership. We emphasize that communication is key to sustainability and provide guidelines for the clear communication between team leaders and university and K–12 schools, and with potential sponsors and community leaders, to build support for project longevity. Sustainable partnerships integrate the core project elements into institutional culture and promote a “change agent” attitude in GK–12 Teachers and Fellows to help them continue to employ new pedagogical and communication strategies. Finally, we provide sources for initial funding and tips for developing a fund-raising plan for sustainability.

LEADERSHIP

We begin with a simple, but often overlooked, point: Sustaining a successful project requires sustained leadership. Even if a project is running smoothly, with logistical kinks removed and no apparent challenges on the horizon, changes in leadership are inevitable and can pose a considerable risk to the project’s health and continuity. On the positive side, changes to a project can be beneficial. In this section, we focus on mechanisms for ensuring smooth transitions in leadership.

Above all, plan ahead. There are countless examples of institutionally “successful” projects that were created and led primarily by one person for many years, so that the projects became inextricably identified with that leader. In such cases, the departure of the person or a reassignment of his or her duties may rob the project of its soul. Long before that happens, current leaders need to identify, recruit, and prepare potential successors. Fortunately, the easiest time to convince someone to accept a large responsibility is well before that responsibility becomes a reality! We recommend that potential recruits be placed on advisory boards or steering committees, providing them with an opportunity to learn how the project functions and to ponder its challenges and opportunities. If they attend meetings regularly and become engaged in activities, they are likely...
to be a good fit for leadership and are much more apt to accept an offer of leadership than if they were approached “cold.”

On the university side, faculty with active research labs may have an edge in marshaling support from university administrators for GK–12 activities; they tend to have institutional clout. Equally important, they generally have experience building and guiding teams of diverse collaborators and are in a position to understand the wide variety of constraints and challenges already imposed on faculty and students. Many GK–12 projects include nontenured faculty members who nonetheless may have more expertise in establishing partnerships with K–12 schools. Faculty from colleges of education may seem like a natural source for recruiting leaders for GK–12 projects. We caution, however, that faculty who are not scientists or engineers will likely encounter a significant cultural divide between their college or department and departments from which GK–12 Fellows are typically drawn. For smaller projects, centered in a department or in a research center with outreach components, education and outreach coordinators can be highly effective.

Because all sustainable GK–12 projects are partnerships between a university and a K–12 school system, leadership from both sides of the partnership is essential. On the university side, we recommend a project director who is a faculty member of a science or engineering department or who already directs a center of science education or outreach. With respect to K–12 leadership, we recommend a science or math teacher with significant classroom experience. In larger districts, this person might have the title of science/math coordinator. The person should be provided with release time and/or compensation from the school district to meet regularly with the project director and the Fellows involved in the project. Assuming that he or she has been fully endorsed by school administrators and is actively engaged in the project’s activities, the designee will be well positioned to respond to problems that inevitably arise in K–12 schools and that might otherwise threaten the long-term health of the project. As with faculty leadership, it is critical to identify, recruit, and train someone for this type of position long before a change in leadership becomes necessary. An alternative model is for school district science coordinators to meet with the project director on a monthly basis. Finally, leadership and guidance can be provided by advisory boards composed of school and university leaders, senior faculty, and GK–12 Fellows and Teachers.

“Education has the capacity to transform, as long as you remember that your present state doesn’t have to be your permanent state.”

—GK–12 Fellow, Howard University

ONGOING COMMUNICATION

All GK–12 projects must engage in ongoing communication (e.g., daily or weekly) with partnering schools and university scientists and researchers. The frequency and means of ongoing communication should be established by the leadership at the beginning of the project. This strategy can help the project team uncover persistent challenges to a project’s implementation and identify potential opportunities. Ongoing communication also helps build sustained, long-term relationships between the university and partnering schools that can help initiate new projects. Ongoing communication with schools may involve email updates on project activities and events, phone conversations to resolve unforeseen setbacks, and at least monthly face-to-face meetings to review the progress of the project. Many projects also make presentations to school boards or to parent–teacher organizations. In this section, we provide tips on establishing and maintaining communication with all stakeholders.

Communicating with Schools

Ongoing communication between a university-based K–12 STEM education project team and teachers in a potential partnering school is paramount to project success. Moreover, the STEM project team must regularly engage with and update school principals, since their implicit and explicit support of project activities communicates to the school’s teachers and staff the importance of the project to the school and its students. GK–12 projects have employed a range of approaches, depending on the size and scope of the project. Some projects span several school districts and others serve a single school. Communication challenges and strategies vary with the scope of the activities and partners. Having participating Teachers give talks at conferences and publish about their work builds support for both the Teachers and administrators, especially when these activities are advertised to school audiences. Some GK–12 projects have annual meetings at which invited faculty mentors and school district personnel publicize the results attained by Teacher–Fellow teams.
Regular communication with school partners allows the project team to identify problems and fix them before they become intractable. For example, if a GK–12 Fellow makes a significant effort to prepare inquiry-based, hands-on STEM lessons, but the GK–12 Teacher fails to provide comments on the length of the lesson or the appropriateness of the language for the intended students, then the Fellow may begin to lose enthusiasm. This type of awkward dynamic between Fellow and Teacher can develop slowly and will eventually erupt; frequent (perhaps scheduled) opportunities for communication throughout the school year can easily prevent such trouble.

Communicating School Needs
Most teaching and learning activities in the K–12 classrooms are driven by learning standards and, increasingly, by pacing charts and student performance data. Teachers have deep familiarity with the standards and how various units, lessons, and activities align with the standards. Thus, if the lessons offered by Fellows are not aligned with the standards, Teachers will not be receptive and the GK–12 project will not be sustainable. Again, ongoing communication between Teachers and Fellows is the solution. To accomplish this, many GK–12 projects have planning meetings of all Teacher–Fellow teams at least once a semester, supporting face-to-face communication about lessons learned, allowing adjustments to be made, and creating a sense of community and teamwork.

Communicating Researchers’ Needs
GK–12 Fellows are often graduate students with many responsibilities on campus, including completing their course work, laboratory experiments, fieldwork, data analysis, exams, writing, and travel. For the Teacher–Fellow partnership to be sustained, it is critical that all stakeholders understand these multiple responsibilities. For example, if a Teacher understands that a Fellow will not attend a previously planned activity because of conflicting professional requirements, then the Teacher will more likely be supportive of the Fellow. In short, the GK–12 Fellows’ overall success and satisfaction is paramount to their sustained participation in any GK–12 project.

FLEXIBILITY AND ADAPTATION
No matter how smoothly a project operates at a given time, change is inevitable. On the one hand, change that results from neglect, misguided leadership, or the type of attitude encapsulated by Mark Twain’s quote, “I’m all for progress. It’s change I can’t stand,” is obviously a threat to sustainability. On the other hand, leaders who can anticipate and respond to shifts in the needs of Fellows, Teachers, faculty, and administrators can help GK–12 projects become more sustainable. The key is to turn challenges into opportunities by seeking input from all involved and responding in an open and deliberate manner.

Many projects allow Teachers and Fellows to negotiate which days the Fellows are in the classroom. For example, in the Problems and Research to Integrate Science and Mathematics (PRISM) GK–12...
project at Emory University, Fellows could be in class for an entire week each month or for one to two days per week. Teachers appreciate this type of flexibility and Fellows sometimes require it. Responding to changes in Teacher assignments and school schedules required flexibility and often meant reassigning Fellows or altering the timing of their commitments.

Flexibility in Project Structure
NSF GK–12 grants provided many projects with initial funding to build partnerships. As funding diminished, projects adapted by finding new ways to sustain graduate student involvement in K–12 classrooms. For example, many projects found institutional resources that subsidized graduate students, albeit for a reduced amount of time, or that replaced a portion of their regular graduate fellowship amounts. Some projects adapted models and materials from other projects, to reduce time commitments and to provide Teachers with exemplary materials. Some projects recruit Fellows and Teachers to disseminate materials and pedagogy through workshops for other Teachers and Fellows. Many projects have continued by collaborating with other university- or school-based strategic initiatives and other projects funded by grants.

INFRASTRUCTURE
Building the infrastructure to continue preparing graduate students for work with K–12 schools and for communicating science is important in sustaining a GK–12 project. The impact of GK–12 projects on graduate students' leadership, communication skills, and teaching is a prime motivator for changes in graduate projects. Some GK–12 projects used courses from their education schools to prepare Fellows for the classroom. Other projects developed their own courses (e.g., “Communicating Science” and “Teaching Science” courses at Emory University and “Presentation Boot Camp” at Florida Institute of Technology). Still other institutions have taken things one step further and implemented undergraduate and graduate courses in which the student’s primary responsibility is to go into the K–12 classroom to work with teachers and students, much as GK–12 Fellows do themselves. Because these courses proved their success, they became institutionalized; that is, they remain as sustainable elements of the GK–12 projects that created them. (See the Emory University exemplar at the end of the chapter.) Some institutions have used these elements as a foundation to create projects that lead to certificates for STEM graduate students, who enroll in the courses to receive formal, documented training in outreach and communication. Projects of this type are relatively easy to establish and sustain because their structure of courses, credits, and faculty assignments is already familiar to universities.

Likewise, developing web archives of lessons and materials is a way to capture the work of GK–12 projects and to extend their impact to other Teachers and schools. (See Table 11.1.) Doing so can foster growth and sustainability because local users will likely become advocates of the project and can contribute in numerous ways that collectively strengthen the project, making it easier to sustain. Over time, archived data and lesson plans represent a library resource as new lesson plans are developed by incoming GK–12 Fellows. As more of these plans are adopted by local schools, the easier it will become to recruit new teachers for the GK–12 project and to ease the transition of new Fellows into local schools, both approaches of which are important for sustainability.

FINDING FUNDING
Sustaining any GK–12 project beyond its current funding term requires systematic planning and the implementation of a fund-raising strategy. Viewing initial support as seed money and identifying key components that stakeholders value leads to continued support. Moreover, the project team must develop a plan that aspires to scale up the project by identifying critical measures of success that will

KEYS FOR SUCCESS
- Embrace the project’s goals and flexibility will facilitate success.
- Allow projects to evolve in scope or structure to meet new challenges or expectations.
- Establish courses or projects to train STEM graduate students in outreach and communication to create a sustainable infrastructure for GK–12 projects.
- Make lesson plans and other resources developed by your project widely available and easily accessible.
- Build on resources already assembled. Archives should contain shared, unique resources.
resonate with future funders and donors. Using quantitative data, as well as qualitative and anecdotal information, project leaders can communicate successes to key constituencies (e.g., students and Teachers of K–12 schools, as well as Fellows, researchers, and faculty at the university).

Collaborating with Other Grant Projects
University-based GK–12 project leaders can engage with leading STEM researchers on their campuses and assist in the planning and design of innovative strategies that (1) bring state-of-the-art research tools and techniques to the K–12 environment; (2) engage Teachers as professionals on university research teams, allowing the Teachers to experience the modern research process and revitalize their own interest in scientific discovery and technological innovation; and (3) excite students about STEM studies through creative, standards-aligned classroom lessons or summer research internships. Many GK–12 projects received support from other grants, such as NSF and NIH Center grants with outreach components; the NSF's Integrative Graduate Education, Research, and Traineeship Program and Science and Technology Centers; and the U.S. Department of Education's Mathematics and Science Partnership grants and Race to the Top funds. Local foundations are another source of sustainable funding (see the exemplars at the end.

### Table 11.1 Websites of Materials Developed by NSF GK–12 Projects

<table>
<thead>
<tr>
<th>Institution</th>
<th>Thematic focus or grade level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idaho State University</td>
<td>Physical and life sciences, and robotics activities, for grades 5–12</td>
</tr>
<tr>
<td>Kent State University</td>
<td>Geoscience activities and lesson plans, and links to and reviews of activities, from the Digital Library for Earth System Education (DLESE)</td>
</tr>
<tr>
<td>Michigan State University</td>
<td>Lessons in general science, biology, ecology, earth science, chemistry, and physics; arranged by grade level</td>
</tr>
<tr>
<td>North Carolina State University</td>
<td>Hands-on lessons with engineering applications</td>
</tr>
<tr>
<td>Penn State University</td>
<td>Multiday standards-aligned instructional modules using the theme of advanced transportation technologies</td>
</tr>
<tr>
<td>University of Colorado</td>
<td>Lessons and activities on the TeachEngineering.org Digital Library Collection that use engineering as a vehicle for hands-on integration of science and math learning</td>
</tr>
<tr>
<td>University of Montana</td>
<td>Ecological inquiries for K–12 and natural history guide for Teachers and students</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elementary School Grades (K-5)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ohio State University</td>
<td>Science investigations for grades 3–5</td>
</tr>
<tr>
<td>St. Joseph's University</td>
<td>Natural science units for grades K–5</td>
</tr>
<tr>
<td>University of Alaska</td>
<td>Activities focused on earth, life, and physical sciences</td>
</tr>
<tr>
<td>University of South Carolina</td>
<td>Inquiry-based engineering, science, and math activities for the K–8 classroom</td>
</tr>
<tr>
<td>University of South Florida</td>
<td>Lessons, experiments, and modules (genetic engineering, biosensors, robotics, and nanotechnology) based on Sunshine State Standards</td>
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<th>Middle and High School Grades (6-12)</th>
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</thead>
<tbody>
<tr>
<td>California State University Northridge</td>
<td>Mathematics activities for middle school and high school students</td>
</tr>
<tr>
<td>Colorado School of Mines</td>
<td>Hands-on middle school mathematics and science activities with connections to engineering</td>
</tr>
<tr>
<td>Cornell University</td>
<td>Resources for science projects developed by graduate and undergraduate students in collaboration with middle and high school Teachers</td>
</tr>
<tr>
<td>Emory University</td>
<td>Problem-based lessons for middle and high school science and math</td>
</tr>
<tr>
<td>Illinois State University</td>
<td>Biology, chemistry, and math lessons</td>
</tr>
<tr>
<td>Texas A&amp;M University</td>
<td>Curriculum materials that support students in grades 6–12 in their use of spatial thinking, GIS, and remote sensing</td>
</tr>
<tr>
<td>University of Alaska</td>
<td>Activities focused on earth, life, and physical sciences</td>
</tr>
<tr>
<td>University of Arkansas</td>
<td>Math and science lessons for students in grades 6 and 7</td>
</tr>
<tr>
<td>University of Central Florida</td>
<td>Inquiry-based lessons geared for upper middle and lower high school students</td>
</tr>
<tr>
<td>University of Florida</td>
<td>Inquiry-based lessons focused mostly on ecosystem health and sustainability for middle schools</td>
</tr>
<tr>
<td>University of Illinois Urbana–Champaign</td>
<td>Chemistry units featuring visualization and models; American history units; inquiries involving water; and geology units featuring visualization of earthquakes and plate tectonics</td>
</tr>
</tbody>
</table>

of the chapter). Graduate Assistantships in Areas of National Need (GAANN) grants from the Department of Education support the development of teaching skills and may be sources of funds for the support of Fellows in GK–12 activities. Such a partnership between the STEM research community and K–12 STEM education projects will be mutually beneficial through new grant awards and will enhance the profile of K–12 STEM education projects within the higher education community. The National Science Foundation website (www.nsf.gov) should be consulted for up-to-date project priorities and initiatives.

Collaboration with Faculty Researchers to Support Broader Impacts
Many federal and state granting agencies and some foundations require recipients of funds to explicitly identify and communicate the broader impact and societal benefits of their research. GK–12 project leaders should offer their experience and expertise to faculty researchers seeking to communicate their research effectively to K–12 Teachers and students. Inviting faculty researchers to GK–12 project meetings, events attended by Teachers, or the project’s K–12 classroom activities can lead to additional funding and foster an institutional culture that values outreach. Faculty who participate can also benefit directly by being able to (1) offer authentic broader impact statements and societal benefit statements in their research proposals and (2) distinguish their research proposals from their competitors’ and increase their likelihood of being funded.

Collaboration with a School of Education to Support Teacher Preparation Projects
Schools of education are the primary resource for numerous educational and professional development projects for pre- and in-service teachers. Yet, they often do not have access to practicing scientists and engineers with considerable content knowledge and current STEM research experience who can convey the excitement of science and engineering to K–12 constituencies. K–12 STEM education projects within schools of science and engineering develop deep and sustained relationships with K–12 constituencies. In a sustainable collaboration, (1) schools of education could conduct professional development for students and faculty at schools of science and engineering and, in so doing, expose them to the science of learning; (2) the partners from both schools could collaborate to develop content-rich, standards-appropriate, and pedagogically relevant K–12 STEM lessons and conduct Teacher professional development projects; and (3) preservice students from schools of education could enroll in challenging, content-rich STEM courses at schools of science and engineering and develop proficiency in lab practice and the process of science. Such a collaborative approach can enable the partner schools to tap into new resources to develop innovative K–12 STEM education projects.

Collaboration with Schools and Districts for State Funding
Many states have adopted national standards for math and science in the K–12 educational system (e.g., the Common Core State Standards for Math and the Next Generation Science Standards). Moreover, frequent calls from industry captains, professional societies, and policymakers are beginning to draw the attention of state and local education officials to shortages in the scientific and engineering workforce. In fact, states such as Massachusetts have developed and integrated academic standards for engineering education at the K–12 level and treat engineering as equivalent to various science disciplines (Foster 2009). Finally, recent federal efforts, such as the Race to the Top, have provided significant financial resources to many state departments of education for planning and implementing innovative STEM

KEYS FOR SUCCESS

- Success builds on success; communicate clearly what your project has accomplished, and provide a vision for continued success.
- Partner with faculty to include current and potential project activities in new grant proposals, especially those which feature broader impacts and education.
- Partner with K–12 schools to provide Teachers with professional development and access to STEM faculty and graduate students.
- Take advantage of state funding opportunities for K–12 activities.
- Work with development officers at universities and school districts to solicit funds from individuals and corporations.
edueation projects to prepare effective STEM Teachers who can educate their students for college readiness and for a competitive global economy.

Therefore, university-based K–12 STEM education projects currently have numerous opportunities to collaborate with local school districts and state departments of education. Specifically, the K–12 STEM education projects can offer their expertise on (1) familiarity with K–12 STEM curriculum and its appropriateness to prepare students for college; (2) the professional development needs of Teachers in STEM content and lab practices; and (3) the appropriate integration of modern scientific and technological tools to educate, engage, and excite students in STEM studies. For example, university faculty can participate in the design of state science and math standards that are aligned with the national core standards. Moreover, university K–12 STEM education projects can help state departments of education prepare teachers in local school districts to implement STEM curriculum with high fidelity to the emerging core standards. Finally, K–12 STEM education projects can offer challenging summer enrichment programs to K–12 students that allow the students to explore career options in STEM disciplines.

Collaboration with Development Teams for Fund Raising

Development teams at universities are tasked with identifying and prioritizing the funding needs of the universities’ various projects. Moreover, these teams develop and maintain a list of philanthropic and corporate foundation projects, as well as a list of prospective individual donors, including university alumni and alumnae. In order to match various university needs with foundation projects and potential donors, development staff spend a good deal of time meeting with faculty and researchers. Many foundations and individual benefactors often support projects that explicitly and convincingly demonstrate a societal impact. Fortunately, university-based K–12 STEM education projects can demonstrate the vast number and kinds of benefits that K–12 students and teachers derive from projects that involve teacher–scientist partnerships in content- and technology-rich classroom instruction or inquiry-based hands-on STEM lessons and activities. Thus, development teams frequently seek out and prominently feature K–12 STEM education projects in their fund-raising activities (Table 11.2).

As development teams partner with K–12 STEM education projects, it is critical to align any proposed project with the funder’s goals. Some funders may be driven by standards-based school or curriculum reform, while others may seek to broaden STEM education opportunities to underrepresented minorities and women. For example, even if a K–12 project is initially funded by a federal or state grant to broaden the educational experience of scientists in training through a Fellow–Teacher partnership (e.g., an NSF GK–12 project), fund raising from foundations and individual donors for sustaining such a project will often require articulation of the benefits of such a project primarily for K–12 constituencies, with the benefits to the scientist in training being secondary. K–12 STEM education projects can facilitate their development teams’ fund-raising campaigns by (1) maintaining a project website that highlights project activities and impacts; (2) keeping data on participants (schools, teachers, students, university-based STEM students, faculty, etc.) current; (3) broadly disseminating outcomes of projects, including announcements about events, accomplishments of project teachers and students, etc., through print media, television, etc.; and (4) acknowledging sources of support in all public communications related to the project. Often, K–12 STEM projects may find it helpful to partner not only with the university’s development team, but also with the media and marketing team, to accomplish their fund-raising goals.

FOR MORE INFORMATION

## Table 11.2 Sources of Grants

### FEDERAL SOURCES OF GRANTS

<table>
<thead>
<tr>
<th>Grant Source</th>
<th>Description</th>
<th>Website/Link</th>
</tr>
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<tbody>
<tr>
<td>Grants.gov</td>
<td>Allows searches by topic area for all federal grants; search for opportunities to extend your project.</td>
<td><a href="http://1.usa.gov/Zy2bGW">http://1.usa.gov/Zy2bGW</a></td>
</tr>
<tr>
<td>The Science Education Partnership Award (SEPA), offered by the National Institutes of Health (NIH)</td>
<td>Funds grants to create partnerships among biomedical and clinical researchers, on the one hand, and K–12 teachers and schools, museums and science centers, media experts, and other educational organizations, on the other hand.</td>
<td><a href="http://www.ncrrsepa.org/">http://www.ncrrsepa.org/</a></td>
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</table>

National Science Foundation projects, www.nsf.gov:

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Description</th>
<th>Website/Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Technological Education</td>
<td></td>
<td><a href="http://1.usa.gov/1ouUK5Q">http://1.usa.gov/1ouUK5Q</a></td>
</tr>
<tr>
<td>Arctic Research Opportunities</td>
<td></td>
<td><a href="http://1.usa.gov/14ClC9E">http://1.usa.gov/14ClC9E</a></td>
</tr>
<tr>
<td>Climate Change Education</td>
<td></td>
<td><a href="http://1.usa.gov/10swbqB">http://1.usa.gov/10swbqB</a></td>
</tr>
<tr>
<td>Cyberlearning: Transforming Education</td>
<td></td>
<td><a href="http://1.usa.gov/XGiJ8R">http://1.usa.gov/XGiJ8R</a></td>
</tr>
<tr>
<td>Dynamics of Coupled Natural and Human Systems</td>
<td></td>
<td><a href="http://1.usa.gov/16tNqeH">http://1.usa.gov/16tNqeH</a></td>
</tr>
<tr>
<td>Innovative Technology Experiences for Students and Teachers</td>
<td></td>
<td><a href="http://1.usa.gov/XbfReH">http://1.usa.gov/XbfReH</a></td>
</tr>
<tr>
<td>Math and Science Partnership (MSP)</td>
<td></td>
<td><a href="http://1.usa.gov/YZ54l5">http://1.usa.gov/YZ54l5</a></td>
</tr>
<tr>
<td>National STEM Education Distributed Learning</td>
<td></td>
<td><a href="http://1.usa.gov/Zy2PnY">http://1.usa.gov/Zy2PnY</a></td>
</tr>
<tr>
<td>Research Experiences for Teachers (RET) in Engineering and Computer Science</td>
<td></td>
<td><a href="http://1.usa.gov/10mjQ81">http://1.usa.gov/10mjQ81</a></td>
</tr>
<tr>
<td>Robert Noyce Teacher Scholarship Project in Cyberlearning: Transforming Education</td>
<td></td>
<td><a href="http://1.usa.gov/10syREw">http://1.usa.gov/10syREw</a></td>
</tr>
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### SOURCES OF GRANTS FOR TEACHERS

<table>
<thead>
<tr>
<th>Grant Source</th>
<th>Description</th>
<th>Website/Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best Buy Teach Award</td>
<td>Rewards schools for creating and implementing successful interactive projects that focus on children using technology to learn standards-based curriculum.</td>
<td><a href="http://bit.ly/14CntLz">http://bit.ly/14CntLz</a></td>
</tr>
</tbody>
</table>


Search for education grants and identify new funding opportunities.

http://www.grantwrangler.com/STEMresources.html

A site with a searchable list of foundations and other organizations that support STEM education.

ING Unsung Heroes® Award

http://www.ing-usa.com/us/unsungheroes/

ING Unsung Heroes helps turn Teachers’ great ideas into reality for students. Each year, 100 educators are selected to receive $2,000 to help fund their innovative class projects. Three of those chosen receive the top awards of an additional $5,000, $10,000, and $25,000.

National Education Association (NEA) Grants


The NEA Foundation awards grants in support of closing achievement gaps, developing creative learning opportunities for students, and enhancing the professional development of teachers.

SchoolGrants

http://www.schoolgrants.org/

A searchable site with many grant sources and resources for effective grant writing, including sample proposals.

The Science Education Grant Index


The index provides access to all the science, math, computer science, engineering, and technology grants covered in recent issues of Technology Grant News.

The Teacher Network

http://Teachersnetwork.org/Grants/grants_science.htm

Lists small-grant opportunities and provides some grant-writing resources.

Toshiba America Foundation

http://www.toshiba.com/taf/

Toshiba America Foundation provides up to $5,000 grants to 6th–12th-grade science and math teachers to acquire instructional equipment that will make learning more exciting for students.

Toyota TAPESTRY Grants for Science Teachers

http://www.nsta.org/pd/tapestry/

Toyota TAPESTRY Grants provide up to $10,000 in awards to implement innovative, community-based science projects in environmental science, physical science, and the integration of literacy and science.
SHARED FINANCIAL SUPPORT FOR SUSTAINABILITY

University of Florida – Science Partners in Inquiry-based Collaborative Education (SPICE)
http://www.spice.centers.ufl.edu/

The sustainability model for SPICE is based on a system of shared financial support for Fellows and a two-tiered structure of those Fellows. Deans from each of the three main colleges that train STEM graduate students have committed one Fellowship ($24,000 plus tuition and fees) per year, with the understanding that the Fellowship will be awarded to a student in the contributing college after an open solicitation for applications that are reviewed by a committee, including a representative from that college. In addition, $500 per year is contributed for classroom supplies. In general, the Fellowships are not a drain on a college’s budget, because the funds are allocated from a relatively large pool of graduate Fellowships that were already in place before the start of SPICE.

When a graduate student accepts a $24,000 SPICE Fellowship, he or she must commit to the project for two successive years. In the first year, Fellows receive training through a two- to three-week summer institute and become Type I Fellows, spending one to two days per week in middle school classrooms, facilitating inquiry-based learning and becoming mentors. The following year, they become Type II Fellows, receiving far less financial support ($4,000) but committing to much less time: They do not need summer training, do not typically need to prepare as extensively for a lesson (because they prepared the same lesson the previous year), and do not need to be in the classroom as frequently as Type I Fellows (two days per month vs. one to two days per week). Of the $4,000 provided, $500 is set aside for classroom supplies. The remaining amount, a $3,500 stipend, is intended to replace a portion of the financial support that the students would otherwise have been provided by their respective departments or colleges. Consequently, it does not include tuition and fees. The $4,000 is provided by four matching contributions of $1,000 from the chair of the student’s department, the dean of the department’s college, the provost, and the vice president for research. Importantly, all parties must agree to this support for a student’s Type II Fellowship before a Type I Fellowship is awarded. This two-tiered system of Fellowships has two important benefits. First, it provides a critical mass of Fellows in a given year (six instead of three). Second, it ensures continuity of people and experiences between years, including experienced peer mentors (Type II Fellows) for incoming participants (Type I Fellows). Most important, the model provides sustainability by creating a multilayered system of shared financial support; the financial obligations of each contributor are relatively small, but all contributors understand that the funds they provide are needed to acquire the necessary funds from other contributors.

BUILDING INFRASTRUCTURE AND FUNDING FOR SUSTAINABILITY

Emory University – Problems and Research Integrating Science and Math (PRISM)
http://www.cse.emory.edu/prism/index.cfm

PRISM uses problem- and case-based learning as its key pedagogical strategies. The project is supported by grant funds and by the Emory Graduate School, the Office of the Provost, Emory College of Arts and Sciences, and the research mentors of the participating Fellows. The institutional support is an essential component of PRISM’s sustainability. The support is strong because of the project’s impact on graduate student training and the extent of its impact in the K–12 community.

For example, PRISM has disseminated project materials and lessons learned through 357 cases published on the CASES Online website (http://www.cse.emory.edu/cases) and 73 presentations and workshops by
graduate students and Teachers at regional, national, and international meetings. Likewise, PRISM has built an increasing web of activities promoting the development of teaching and communication skills for graduate students (e.g., a course titled “Communicating Science”; see below). PRISM has even been effective in unanticipated ways that strengthen Emory’s mission of fostering undergraduate education. In particular, several veteran Fellows collaborated with faculty to enhance undergraduate courses in anthropology, biology, chemistry, and psychology with problem-based learning techniques. Altogether, these resources and activities have created a sustainable project because they are so tightly integrated and constitute such an important part of Emory’s Center for Science Education that it would be difficult for administrators to withdraw support.

The “Communicating Science” course at Emory provides an introduction to communicating science through “elevator speeches,” essays, science journalism, web communications, and teachable units for science cafés, undergraduate courses, and teacher workshops. The course teaches methods and content necessary for writing and communicating about science to general audiences. Through assigned readings, guest speakers, class discussions, student projects, and assignments, students learn different styles of communicating science to a variety of audiences. Students learn to think creatively about how best to communicate their research to different target audiences. Toward this end, students create a portfolio that reflects their ability to teach to different groups of people.

PRISM has also achieved sustainability by seeking outside funding. For example, the Arthur M. Blank Family Foundation has provided funds for several years to support graduate students, undergraduates, and teachers in problem-based learning. Similarly, PRISM has offered Fellowships to graduate students and Teachers from the Coan Middle School through a Learn and Serve Georgia grant and the donor-funded Graduation Generation project. Additional support has come through a partnership with an NSF CREST center at Clark Atlanta University.

Continuing growth in the PRISM team’s expertise in problem-based learning (PBL) curriculum has led to partnerships with other Emory projects as well. For example, PRISM staff members and former Fellows train medical students and undergraduates in PBL facilitation to prepare them to lead the Emory Pipeline Project (an after-school experience for high school students). Moreover, the PRISM team continues to hold PBL pedagogy sessions during its numerous professional development workshops for teachers unaffiliated with its GK–12 project. Finally, the PRISM team has developed a new partnership with Morehouse College and Clayton County schools, under which it will offer teacher workshops on PBL pedagogy and new case materials.

Since 2008, PRISM coordinator Jordan Rose has led teaching modules as part of the course numbered NS570R: “Neuroscience: Communication & Ethics.” In four to eight sessions each year, Rose guided graduate students as they developed lessons for K–12 science courses, practiced implementing those lessons among their peers, and then implemented the lessons in real public school classrooms as part of Emory’s Brain Awareness Month outreach activities in March.

A MULTIFACETED STRATEGY FOR SUSTAINABILITY

Polytechnic Institute of New York University (NYU–Poly)
http://gk12.poly.edu/amps-cbri/ and http://raise.poly.edu

The sustainability of project RAISE (Revitalizing Achievement by using Instrumentation in Science Education) has been driven by a constant outreach to the university, schools, community leaders, and public and private grant-making agencies. RAISE’s outreach efforts have focused on communicating the successes of GK–12 Fellows and Teachers to the university and school leaders. Moreover, the project directors sought financial support from funding agencies for an array of synergistic activities. Sustainability efforts focused on three constituencies: Fellows, schools, and the university.

To raise funds from philanthropic foundations, the directors of the RAISE project teamed up with the university’s Office of Corporate and Foundation Relations. Together, they highlighted the GK–12 project approach to embed scientists and engineers with content expertise so as to support school Teachers and enrich STEM education of underrepresented students, while addressing the K-20 STEM pipeline issue.
The project team received grants from the Independence Community Foundation of New York, the J.P. Morgan Chase Foundation, and the Hebrew Technical Institute, allowing the team to support 14 Fellows who collaborated with Teachers to enrich classroom science and math through hands-on engineering activities.

Both NYU-Poly and its partner schools invested significant funds to acquire modern sensing and data acquisition equipment, which remains at the participating schools on a permanent basis. Therefore, even after the conclusion of the RAISE project, most RAISE Teachers were able to continue the sensor-based curriculum in their classes – strong evidence of sustainability. The project team conducted several teacher professional development workshops, which included nearly 60 non-RAISE teachers, to broaden and sustain sensor-based labs in the high schools. A grant from the New York State Education Department supported a “Summer Workshop in Instrumentation, Sensors, and Engineering.” Sensor-based projects, adopted from the RAISE effort, introduced 20 teachers from Lower Hudson, Long Island, and New York City school districts to hands-on engineering design in a two-week summer workshop (Iskander et. al. 2010).

One of the project directors created a graduate-level course titled “Instrumentation, Monitoring, and Condition Assessment of Civil Infrastructure” (Iskander et al. 2009). Since 2006, this course has been offered annually at NYU–Poly with an enrollment of 25 to 30 students. Over 300 practicing engineers have taken a continuing education version of the course through the American Society of Civil Engineers.

Finally, in summer 2007, under the support of the Independence Community Foundation of New York and the J.P. Morgan Chase Foundation, the Central Brooklyn Robotics Initiative (CBRI) began as a pilot program for the AMPS (Applying Mechatronics to Promote Science) GK–12 project, and it has synergistically supported the AMPS project since its initiation in 2008. From 2008 to 2010, the AMPS–CBRI effort received a series of additional awards from the Independence Community Foundation of New York, J.P. Morgan Chase Foundation, Motorola Foundation, and New York Space Grant Consortium. Beginning in spring 2010, the CBRI was transformed into the Central Brooklyn STEM Initiative (CBSI), to scale up the AMPS–CBRI effort from 12 schools in 2009–2010 to 36 schools over three years. The AMPS–CBSI project has received a series of single- and multiyear awards from the Black Male Donor Collaborative, Brooklyn Community Foundation, Daniel and Joanna Rose Foundation, J.P. Morgan Chase Foundation, Motorola Foundation, New York Space Grant Consortium, White Cedar Fund, and Xerox Foundation. In 2011–2012, the AMPS–CBSI project is supporting seven doctoral and seven master’s Fellows who are working with nine faculty, 23 Teachers at 23 schools, and over 1,650 students. This public–private partnership has allowed the AMPS project to support an additional 19 graduate Fellows from non-NSF funds.

Numerous standards-aligned STEM lessons, which utilize LEGO-based automated lab apparatuses and robotics devices, have been developed and class-tested by Fellow–Teacher teams and are available at http://gk12.poly.edu/amps-cbri/html/resources/classroom.html. To facilitate the sustainability of its robotics-focused K–12 STEM lessons and to expedite the migration of out-of-school LEGO robotics projects into STEM classrooms, the AMPS project team continues to conduct “Teaching STEM with Robotics” workshops.
Recent published education policy documents underscore the components of successful STEM projects at both the postsecondary and K–12 levels (National Research Council [NRC] 2011 and 2012, President’s Council of Advisors on Science and Technology [PCAST] 2012). These documents emphasize systemic changes in STEM teaching and learning for all students, especially those of underserved and underrepresented groups.

For example, the recently released report from PCAST, Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics (2012), makes the following recommendations to postsecondary educators to address the challenge of producing 1 million additional STEM college graduates over the next 10 years: (1) adopt empirically validated teaching practices, (2) advocate discovery-based research courses, and (3) encourage communication and partnerships among stakeholders. These are also goals of the GK–12 approach to training STEM graduate students, who are the gateway not only to cutting-edge science, but also to both educating undergraduates and communicating to the general public.

Similarly, on the K–12 front, recommendations have surfaced for teaching and learning. Successful K–12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics (NRC 2011) emphasizes the need for Teachers with “high capacity to teach in their discipline” (p. 20). Such capacity requires STEM Teacher professional development that (1) focuses on developing Teachers’ pedagogical content knowledge; (2) facilitates teaching in the classroom; and (3) provides multiple and sustained opportunities. A Framework for K–12 Science Education (NRC 2012) recommends the need for K–12 learning experiences that engage students with fundamental questions about the world and provide opportunities to carry out scientific investigations and engineering design projects in the spirit that “scientists have investigated and found answers to those questions” (p. 9).

The GK–12 approach exemplifies STEM education project recommendations in recent policy documents.

This chapter gives indicators for the success of the GK–12 approach in graduate student as well as K–12 Teacher and student populations.

GK–12 Fellows strengthen their teaching, communication, research, and teamwork skills.

The GK–12 approach has shown positive effects on Teacher understanding: an expansion of STEM content knowledge and skills, an increased awareness of STEM research, and elevated confidence in teaching STEM subjects.

The GK–12 approach facilitates teacher professionalism by encouraging teachers to act as mentors and as part of a teaching and learning community.

K–12 students—especially those underserved or underrepresented—involved in GK–12 projects show enhanced understanding of, and increased interest in, STEM content, skills, and careers.
The proliferation of STEM partnership projects in the country, including the more than 300 funded through the NSF GK–12 program, and the numerous research publications resulting from these partnerships show that institutions embracing the GK–12 approach are successful at addressing these recommendations. However, lacking in the literature is any study that provides a synthesis of these publications and their quantifiable impacts on graduate students and GK–12 Teachers. This section addresses that need by documenting the evidence supporting the success of the GK–12 approach at meeting the pressing needs in STEM education.

ASSESSING OUTCOMES FOR GRADUATE STUDENTS

Graduate students are motivated to participate in STEM partnerships for both personal and professional reasons (Abt Associates, Inc. 2010). Many find it rewarding to participate in classroom activities and interact directly with K–12 students with the goals of instilling positive attitudes toward science and improving academic achievement. Working in K–12 classrooms also provides opportunities for graduate students to collaborate with Teachers, both to explore teaching practices and ways of enhancing student learning and to develop and fine-tune their own communication and presentation skills. Using a variety of assessment and evaluation techniques, a number of studies have documented the realization of these anticipated outcomes (Busch and Tanner 2006, Ferreira 2007, McBride et al. 2011, Mitchell et al. 2003, Moskal et al. 2007, Stamp and O’Brien 2005, Thompson et al. 2002, Trautmann and Krasny 2006). For example, nearly all (more than 90%) of former Fellows participating in a retrospective evaluation of NSF’s GK–12 program indicated that participation in the STEM partnership improved their abilities in a variety of communication, teaching, and teamwork activities (Abt Associates, Inc 2010).

Potential outcomes for graduate students participating in STEM partnerships vary with the nature and structure of the project, but most fall within one or more of four general categories: (1) greater understanding and mastery of teaching skills; (2) enhanced communication skills, especially the ability to explain STEM concepts to nonspecialists and nonscientists; (3) increased teamwork and collaborative skills; and (4) improved research skills and understanding of the relevance of their research to society. Although evaluation activities and instruments may be designed to target a single anticipated outcome, multiple outcomes may be assessed simultaneously. For example, a single observational protocol might be used to evaluate both presentation skills (e.g., delivery, presence, organization) and related teaching skills (e.g., audience engagement, questioning skills, connecting to prior understanding).

Improved Teaching Skills and Knowledge of Pedagogy

As with GK–12 Teachers, Fellow–Teacher partnerships enrich the training of graduate students by providing opportunities to discuss and experiment with teaching practices aimed at enhancing student learning. As part of their involvement in STEM partnerships, Fellows often receive formal training in basic pedagogy, including learning and teaching styles, classroom management and assessment techniques, lesson plan design and development, and inquiry-based teaching methods. When this training is combined with practical training and experience in the classroom, participants develop an appreciation for the challenges faced by Teachers and become familiar with the culture of K–12 schools. Over time, they gain insights into the needs, interests, and capabilities of K–12 students and use this knowledge to design new STEM lessons. Consequently, it is not surprising that improved teaching skills and confidence with inquiry-based strategies are common outcomes of GK–12 projects nationwide (McBride et al. 2011, Stamp and O’Brien 2005, Thompson, Collins, et al. 2002, Thompson, Metzgar, et al. 2002, Trautmann & Krasny 2006). Additional evidence is provided in the results of the aforementioned retrospective analysis of the GK–12 program (Abt Associates 2010): More than 95% of the current Fellows responding to the survey agreed
that their GK–12 experiences enhanced their ability to develop instructional materials, teach STEM concepts, and generate student interest in STEM activities. Similarly, an analysis of pre- and post-Fellowship survey data by McBride et al. (2011) indicated that Fellows’ self-perceived skill levels increased in all areas surveyed, including teaching different grade levels, curriculum development, teaching methods, and assessment and management.

Enhanced Communication and Public-Speaking Skills
The potential for skill development through participation in STEM partnerships extends beyond teaching to include improved communication and public-speaking skills. Within the research and academic communities, there is a growing need for scientists to communicate and explain the nature and results of scientific research effectively to a variety of audiences (Baron 2010, Leshner 2007, Lubchenco 1998, NRC 2010 and 2011, Somerville and Hassol 2011). Yet, most graduate programs fail to require training that targets either communications skills or best practices for translating and relating science discoveries to nonscientists. Thus, STEM partnerships provide structured settings for graduate students to hone their communication skills and to practice sharing their research findings with persons outside their field. Moreover, the opportunity to improve communication skills is one of the top anticipated or expected gains cited by graduate students interested in participating in STEM partnerships (McBride et al. 2011). Comparable experiences are less common in more traditional graduate programs. Both master’s and PhD students participating in a retrospective evaluation of the NSF GK–12 program reported a greater involvement in explaining STEM concepts to nontechnical audiences than their non-GK–12 peers (Abt Associates, Inc 2010). Fellows also were more likely to agree that their GK-12 experience and training improved their ability to explain STEM concepts to nonscientists.

Although it is common for projects to rely on self-reported data or self-perceived skill levels obtained through interviews and surveys in order to gauge the impact of a K–12 partnership on scientists, communication growth has also been measured with the use of more quantitative and objective criteria. Sevian and Gonsalves (2008) developed a rubric for assessing the quality of scientific explanations by graduate students. The rubric is based on the same structure used to describe effective teaching and includes an evaluation of the presenter’s pedagogical and content knowledge, as well as the presenter’s ability to integrate the two when explaining his or her research to audiences of nonscientists (Shulman 1987, Sevian & Gonsalves 2008). The protocol is applicable in a variety of contexts and can be used to measure communication growth (e.g., in a comparison of baseline vs. postintervention performance outcomes), to identify strengths and weaknesses in presentation skills of individual scientists, and to assess the effectiveness of new graduate training projects.

Similarly, Tankersley and colleagues (2012) developed a performance-based assessment of oral presentation skills (the Presentation Skills Protocol, or PSP) to track individuals’ skill improvement and to assess the impact of the GK–12 experience on the communication skills of graduate students participating in the Integrated Science Teaching Enhancement Project at Florida Tech. The PSP focuses on 11 presentation skill sets: organization, accuracy, relevance, message, language, equity, delivery, technology, use of time, questions, and presence. It includes a detailed rubric that operationally defines each skill set at three categorical levels of competence: (1) proficient; (2) developing; and (3) needs attention. The PSP was used to provide students with regular and consistent feedback on the quality and effectiveness of their classroom and research presentations. The instrument is used to inform the design of professional development activities and training projects that target specific presentation skills.

However, use of the PSP alone did not guarantee communication growth or competence in the Fellows it assessed. Significant gains in most presentation skill areas were achieved only when a three-pronged approach was taken: (1) formal training was given in best practices and techniques for preparing and delivering presentations (e.g., semester-long courses or intensive professional development workshops focusing on communication skills); (2) frequent opportunities were provided to practice and hone presentation skills (e.g., presentations at professional meetings and informal science centers, as well as in K–12 classrooms); and (3) regular individualized and structured feedback was given (e.g., via the PSP).

Ability to Work Cooperatively on Teams
Graduate students in STEM partnerships must be able to work effectively on teams. STEM partnerships also rarely operate in isolation and are typically part of a larger project that includes multiple teams.
As a consequence of their participation in the partnership, Fellows report that they gain collaborative skills and a better understanding of what it takes to be an effective partner. They value the skills and insights their partner contributes to the team. Within the GK–12 project, Fellows rank working as a team as one of the top benefits associated with their experience (Abt Associates 2010). Nearly a third of the Fellows in the University of Montana's GK–12 project (ECOS) identified improved interdisciplinary teamwork and collaboration as the greatest benefit of participating in the project (McBride et al. 2011). Research advisors have a similar perception of the effect of GK–12 experiences on participants' collaborative skills. More than two-thirds indicated that the experiences had improved Fellows' abilities to work on or lead a team (Abt Associates 2010).

Improved Research Skills and Better Understanding of the Relevance of Their Research to Society

STEM partnership experiences not only provide Fellows with practical training in teaching and science communication, but also contribute to their development as researchers. For example, graduate students participating in San Francisco State University's Science Education Partnership and Assessment Laboratory (SEPAL) GK–12 partnership reported that the pedagogical training and teaching experience they received improved the way they practiced science, broadened their view of scientists, and changed their perception of the role of scientists in K–12 science education (Busch and Tanner 2006). Other studies have reported that teaching fundamental and complex science concepts to K–12 students required the Fellows to take a "big picture" view of their research area and frame it in a context relevant to those students (McBride et al. 2011, Mitchell et al. 2003, Stamp and O'Brien 2005, Trautmann and Krasny 2006). They were also forced to consider the connections among science disciplines and reflect on the relevance of their own discipline to potential stakeholders. Thus, as a consequence of their participation in K–12 outreach, Fellows come to appreciate the importance of engaging in activities and concepts that are relevant to the lives of K–12 students. They reflect on the ways in which their work affects society, and they gain insights into strategies that broaden the impact of their research through education, outreach, and mentorship.

The benefits of graduate teaching experiences (including K–12 teaching partnerships) vis-à-vis the development of both Fellows' research skills and students' performance have been documented in several reports (French and Russell 2002, McBride et al. 2011, Trautmann and Krasny 2006). Although these findings are based largely on self-reported attributions and perceptions, Feldon et al. (2011) recently used a performance-based assessment tool to evaluate similar claims. They compared and evaluated written research proposals prepared by two groups of graduate students: those with both combined research and teaching responsibilities (as either a teaching assistant or a GK–12 Fellow) and those with only research responsibilities. Students who both taught and conducted research demonstrated greater improvement than their counterparts did in several research-related skills, including generating testable hypotheses and designing valid experiments.

Assessing K–12 Teacher and Student Outcomes

Assessing the K–12 Teacher and student outcomes of a STEM project involves establishing goals and objectives as well as strategies to achieve them; however, such evaluation in the school setting is complex for several reasons. First, schools are distinct cultures that influence the outcomes of these partnerships. Second, each partnership is different, as are the participant groups, such as the Teachers and students that constitute them. Finally, STEM partnerships create changes in Teachers' and students' approaches to teaching and learning STEM, and since change is a process, it is difficult to measure and must be documented over time. Keeping in mind these complexities is critical to evaluating the outcomes of, and understanding the dynamics behind, any thriving partnership.

According to the Small Schools Project (2012), each K–12 school has a unique culture that includes not only the obvious demographics, curriculum, schedules, and policies, but also the social elements of communication, collegiality, support, and traditions that give the school its "personality." This multifaceted culture influences the context of the STEM partnership as well as its outcomes. In the current era of educational accountability, evaluative data sources such as test scores and surveys that generate numbers may shed light on how well a partnership is working. However, numbers tell only part of the story. Using a multiplicity of methods,
research studies evaluating STEM partnerships depict the ability of these partnerships to foster positive changes in Teachers and students.

ASSESSMENT OF K–12 TEACHERS
A STEM partnership may facilitate changes in a Teacher, both as a professional and as a member of a learning community. Teachers may grow professionally in terms of knowledge about STEM topics, interest in teaching about them, and facility in orchestrating STEM lessons and other endeavors. Similarly, the collaborative aspect of the STEM partnership fosters an environment that provides Teachers access to resources as well as a voice within the STEM professional learning and research communities.

Enhanced Pedagogical Content Knowledge
Classroom teachers are professionals who possess a specialized type of knowledge termed pedagogical content knowledge (PCK), which includes knowledge, skills, and dispositions that influence the delivery of the enacted curriculum (Shulman 1987). STEM partnerships act as a catalyst in at least four domains of a teacher’s PCK: (1) the development or expansion of science content knowledge; (2) the development or enhancement of skills; (3) an understanding of the nature of science, including awareness of cutting-edge research; and (4) the enhancement of the affective domains of confidence, enthusiasm, facility, and motivation (Gengarelly and Abrams 2008, Mitchell et al. 2003, Raju and Clayson 2011, Thompson, Metzgar, et al. 2002). An example of this catalytic effect displayed in all domains is demonstrated in a retrospective evaluation of the NSF-funded GK–12 program. The majority of the 740 Teachers who responded to the survey reported growth in one or more PCK domains, as is synthesized and encapsulated in Table 12.1.

Another STEM partnership, Columbia University’s Summer Research Project, provided research experiences for middle and high school teachers from New York City’s public schools. The partnership enhanced participating teachers’ ability to communicate science to students (Silverstein et al. 2008, Mitchell et al. 2003, Raju and Clayson 2011, Thompson, Metzgar, et al. 2002). An example of this catalytic effect displayed in all domains is demonstrated in a retrospective evaluation of the NSF-funded GK–12 program. The majority of the 740 Teachers who responded to the survey reported growth in one or more PCK domains, as is synthesized and encapsulated in Table 12.1.

Table 12.1: Teachers’ Perceived Effect of STEM Partnerships on Enhancement of Pedagogical Content Knowledge (PCK)

<table>
<thead>
<tr>
<th>Domains of PCK</th>
<th>To Some Extent</th>
<th>To Great Extent</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEVELOPMENT OR EXPANSION OF SCIENCE CONTENT KNOWLEDGE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased knowledge of content taught</td>
<td>46%</td>
<td>27%</td>
<td>73%</td>
</tr>
<tr>
<td>Expanded knowledge beyond content taught</td>
<td>42%</td>
<td>24%</td>
<td>66%</td>
</tr>
<tr>
<td>DEVELOPMENT OR EXPANSION OF SKILLS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased manipulative activities in instruction</td>
<td>37%</td>
<td>37%</td>
<td>74%</td>
</tr>
<tr>
<td>Increased use of technology</td>
<td>32%</td>
<td>18%</td>
<td>50%</td>
</tr>
<tr>
<td>UNDERSTANDING THE NATURE OF SCIENCE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased knowledge of what researchers do</td>
<td>34%</td>
<td>29%</td>
<td>63%</td>
</tr>
<tr>
<td>Awareness of cutting-edge research</td>
<td>36%</td>
<td>19%</td>
<td>55%</td>
</tr>
<tr>
<td>ENHANCEMENT OF AFFECTIVE DOMAINS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased confidence in teaching STEM</td>
<td>31%</td>
<td>25%</td>
<td>56%</td>
</tr>
<tr>
<td>Increased confidence in using STEM resources</td>
<td>38%</td>
<td>24%</td>
<td>62%</td>
</tr>
<tr>
<td>Increased confidence in using manipulative activities</td>
<td>36%</td>
<td>29%</td>
<td>65%</td>
</tr>
<tr>
<td>Increased engagement with informal STEM activities</td>
<td>32%</td>
<td>20%</td>
<td>52%</td>
</tr>
</tbody>
</table>


echoes that in which GK–12 Teachers’ perceived that the greatest impact of their experience was how the teaching Fellows’ pedagogical competence enhanced their own abilities and improved their teaching (Abt Associates, Inc. 2010).

Furthermore, Thompson (2003) reported that involvement in the GK–12 initiative was a vehicle for exploring Teachers’ understanding of the nature of science and scientific inquiry. In his cross-case analysis, Thompson explored the interactions between practicing Teachers and graduate teaching Fellows. He identified five scaled components of an inquiry framework: methodological, subjective, empirical, tentative, and creative. The portrayed range of each component on a continuum dictated whether the Teacher understood inquiry to be technical (rigid, more like scientific method) or substantive (fluid, more like science). Thompson’s work suggested that involvement in the STEM partnership helped Teachers to improve their understanding of inquiry and the nature of science,
their scientific literacy, and ultimately, their teaching. Similarly, a case study of four Teachers who participated in 225 hours of constructivist teaching that modeled pedagogical techniques through a GK–12 project showed that the positive effects are lasting. Two years after completion of the project, the observations of the Teachers’ classrooms revealed that (1) personal relevance, (2) scientific uncertainty, (3) a critical voice, (4) shared control, and (5) student negotiation were integral parts of the Teachers’ lessons (Beamer, et al. 2008).

Improved Access and Voice
Besides enhancing pedagogical content knowledge, STEM partnerships improve teachers’ access to communities that provide professional development and support. For example, 136 of the principal investigators associated with the GK–12 program reported that their research communities provided participating Teachers with STEM consultation (95%), equipment and materials (75%), access to university resources (73%), opportunities to present at conferences (65%), and additional workshops and training (42%); clearly, this type of support is outside the average teacher’s experience (Abt Associates, Inc. 2009).

Evaluating a GK–12 cohort group of 12 Fellows and 10 Teachers in the collaborative Graduate Teaching Fellows Project at Vanderbilt University, Thompson, Metzgar et al. (2002) found that one or more of three types of professional learning communities ensued from their partnership: (1) within-classroom communities that focused on collaborations between Fellows and Teachers in individual classrooms; (2) between-classroom communities in which multiple Fellows and Teachers would plan and prepare together; and (3) beyond-classroom communities in which Fellows were able to extend learning beyond the school setting.

For example, a within-classroom community provided the arena for one Teacher to grow in her understanding of the nature of science. This was demonstrated by her willingness to discuss and debate knowledge of science concepts with the Fellow in the presence of students, hence providing students a model for taking intellectual risks and using argumentation to establish scientific understanding. Similarly, beyond-classroom communities provided workshop opportunities for Teachers to make professional connections with university mentors, sister schools, and community resources, as well as professional development opportunities for Teachers to branch out into areas such as presenting at a conference, publishing in a journal, and engaging in additional research experiences.

Summary of K–12 Teacher Assessment
Research on the impact of STEM partnerships on teachers shows two general indicators for assessment: growth in teachers’ pedagogical content knowledge and growth in their willingness to form partnerships outside their school community. With regard to pedagogical content knowledge, evaluators should be mindful of growth in the following domains: (1) an expansion of content knowledge, both STEM knowledge for the classroom and current research knowledge to enrich classroom examples; (2) the development or expansion of skills such as integration of technology and authentic inquiry; (3) increased awareness of what researchers do and how they do it, as demonstrated in teachers’ approaches to inquiry-based teaching and incorporating examples of cutting-edge research into their teaching; and (4) increased confidence teaching STEM, using resources and hands-on materials. As regards partnerships, evaluators should see teachers exhibiting indicators that they belong to a professional teaching and research community, collaborating with partners inside and outside the school setting to find intellectual support, equipment and materials, and workshop and training opportunities.

ASSESSMENT OF K–12 STUDENTS
Teachers’ participation in STEM partnerships also fosters changes in their students. Interactions
with STEM professionals may precipitate growth in students’ STEM knowledge base, both intellectually and affectively. Students often increase their depth of understanding in STEM intellectual domains, such as content knowledge, technological skill, scientific reasoning, and the nature of science; however, growth in affective domains, such as increased confidence in STEM learning, as well as an increased interest in and appreciation of STEM topics, STEM professionals, and STEM careers (Abaid et al. 2011, Marx et al. 2006, Thompson and Lyons 2010) is also noted. The majority of the 740 Teachers surveyed retrospectively regarding the perceived effect of their GK–12 STEM partnership reported increases in their students’ STEM intellectual and affective domains as indicated in Table 12.2 (Abt Associates, Inc. 2010).

### Enhanced Understanding of STEM Content, Skills, and Careers

STEM partnerships enhance students’ understanding of content knowledge, skills, and careers. Most often, this enhancement cannot be measured by a standardized test, because it is difficult to quantify. However, the aforementioned study by Silverstein et al. (2009) noted that partnership projects have the potential to raise students’ science scores on standardized exams, and this may be particularly important to students coming from poverty or with learning disabilities. Powers et al. (2008) explored the learning of math students in grades 5 through 8 and their Teachers who were involved in one of several STEM partnership projects between Clarkson University and St. Lawrence County schools in northern New York. Students who were identified with poverty or a learning disability achieved statistically better on the New York math assessments if they had a Teacher who participated in a partnership. This effect could be related to students’ increased interest in STEM topics because of the partnerships.

A study by Beghetto (2009) explores this idea. With regard to the nature of science, an important attribute of scientific thinking is the willingness to take risks. Although higher ability students are significantly more likely to engage in intellectual risk taking than those with lower ability, the GK–12 project data from Beghetto’s study suggested that students’ interest in science, creative self-efficacy, and perceptions of Teachers were uniquely and significantly related to their reports of intellectual risk taking. So STEM partnerships that increase interest, self-efficacy, and perceptions may influence achievement regardless of ability.

<table>
<thead>
<tr>
<th>Domains of STEM Knowledge</th>
<th>Minor Positive Impact</th>
<th>Major Positive Impact</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INTELLECTUAL</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased knowledge of STEM content</td>
<td>44%</td>
<td>52%</td>
<td>96%</td>
</tr>
<tr>
<td>Increased knowledge of STEM current research</td>
<td>50%</td>
<td>31%</td>
<td>81%</td>
</tr>
<tr>
<td>Increased analytical skills</td>
<td>59%</td>
<td>29%</td>
<td>88%</td>
</tr>
<tr>
<td>Increased knowledge of STEM careers</td>
<td>48%</td>
<td>43%</td>
<td>91%</td>
</tr>
<tr>
<td><strong>AFFECTIVE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest in learning STEM content at school</td>
<td>34%</td>
<td>60%</td>
<td>94%</td>
</tr>
<tr>
<td>Interest in taking advanced STEM courses</td>
<td>51%</td>
<td>26%</td>
<td>77%</td>
</tr>
<tr>
<td>Interest in extracurricular STEM activities</td>
<td>38%</td>
<td>29%</td>
<td>67%</td>
</tr>
<tr>
<td>Engagement in informal STEM activities</td>
<td>51%</td>
<td>30%</td>
<td>81%</td>
</tr>
<tr>
<td>Interest in STEM careers</td>
<td>48%</td>
<td>43%</td>
<td>91%</td>
</tr>
</tbody>
</table>

**Table 12.2: Teachers’ Perceived Effect of STEM Partnerships on Students’ STEM Knowledge**


Furthermore, a unique component of the GK–12 STEM partnership model allows graduate students to assist with inquiry-based teaching, in turn leading to students enhancing their own understanding of the process of science. Gengarelly and Abrams (2008) noted that when 10 Fellows worked with high school science students on inquiry-based science projects for one academic year, students (1) gained an understanding of scientific concepts and the process of doing science; (2) increased their ability to formulate questions and derive answers; (3) enhanced their skills; and (4) improved their attitudes toward science.

In addition, students construct knowledge about STEM careers and STEM professionals. Thompson and Lyons (2010) studied the effects of the presence of engineers on high-poverty, low-performing upper elementary and middle school science students in the Engineering Fellows Project, a yearlong GK–12 project that partnered engineering students with the schools. The authors found significant differences in the perceptions of engineers between the group of 44 African-American students participating in the project and the matched control group that had not participated in the project. The participating students were more likely to perceive engineers as designing, presenting, and experimenting; the students also
displayed greater awareness and understanding of various engineering fields.

**Increased Interest in STEM Content, Activities, and Careers**

Partnerships can increase student interest in STEM content, activities, and career paths, especially on the part of students in underserved, high-poverty populations. Many research studies document the positive effects of these partnerships. For example, Powers et al. (2008) note that students in grades 7–9 from some of the poorest and neediest rural K–12 schools in New York State who participated in either in-class K–12 problem-based learning projects or extracurricular VEX robotic projects recognized the importance of understanding STEM disciplines to solve real-world problems.

Similarly, as they facilitated a seven-module inquiry-based anatomy unit, a group of Fellows in medicine saw the interest and commitment of a group of high school biology students increase (Marx et al. 2006). At the onset of the unit, informal observations revealed that most of the students were apathetic toward science and school in general, planning to enter the workforce directly out of high school. On average, only 40% of these students took the SAT from 1996 to 2001, and less than half scored above a combined 1,000 on the verbal and math portions of the test. Because of the extended scientist–student interactions provided by the unit, the scientist stereotype was broken down, as indicated by an evident increase in the students’ excitement in science and scientific careers. Students asked questions about “what a scientist actually does in a laboratory, what college is like, what graduate school is like, and how to become a scientist/engineer” (p. 147). Researchers noted the improvement in science understanding, but also the changes in the students’ perceptions of careers in science.

These findings were echoed in other studies. Kinne et al. (2004) found that their GK–12 project reported a 50% increase in K–12 classroom students’ interest in engineering and an 83% increase in their confidence to learn math and science. Mitchell et al. (2003) found that the presence of GK-12 Fellows in STEM courses provided many students with a role model “who is really enthusiastic, who is interesting, and is also a buddy to the kids” (p. 15). Teachers in Mitchell et al.’s study believed that the presence of positive role models would increase the likelihood that their students would attend college.

**Summary of K–12 Student Assessment**

Research on the impact of STEM partnerships on K–12 students shows two general indicators for assessment: growth in students’ intellectual domains and growth in their affective domains. With regard to students’ intellectual domains, evaluators should explore growth in areas of understanding of STEM content and current STEM research; knowledge of STEM professionals and what they do; and ability to use analytical, technological, and inquiry skills, such as intellectual risk taking, to approach STEM topics. For the affective domain, evaluators should also note the effect of STEM partnerships on students’ interest in STEM topics and careers both inside and outside the classroom, as demonstrated by the students’ engagement in classroom learning, advanced STEM courses, extracurricular STEM activities, and informal STEM activities. Although students have shown improvement in some standardized assessments in the state of New York (Powers et al. 2008, Silverstein et al. 2009), it is important to be mindful of the fact that most often standardized STEM content tests are not evaluating the indicators of growth we are hoping to enhance by STEM partnerships.

**GK–12 APPROACH ANSWERS CALL FOR STEM REFORM**

Science, mathematics, engineering, and technology (STEM) are fundamental aspects of our lives as “citizens, workers, consumers, and parents” (NRC 2011, p. 3). Recent indicators suggest that many students, particularly those from underserved and underrepresented populations, do not have the STEM background to successfully perform in STEM disciplines in college, compete for employment, or engage in personal and societal decisions. Furthermore, if the United States is to maintain its historical prominence in STEM fields, approximately 100,000 professionals will be needed in the next 10 years (NRC 2011, PCAST 2012).

Partnering STEM graduate students with students in K–12 schools not only benefits both sets of students, but also is a successful way to address the societal demand for a STEM-educated populace. Implementation of the GK–12 approach facilitates opportunities for STEM graduate students to broaden their experiences with research-based teaching practices, to enhance their communication skills, to work cooperatively, and to improve their research skills. Such outcomes have recently been recommended to the U.S. president (PCAST 2012) as a way to address the deficit of STEM.
undergraduates and produce the next generation of STEM professionals, particularly in underrepresented groups. In addition, GK–12 partnerships provide Teachers with opportunities to enhance their pedagogical content knowledge while belonging to supportive learning communities; this is a characteristic of professional development seen in STEM Smart Schools and proposed for successful STEM education (NRC 2011). Finally, GK–12 partnerships facilitate an enhanced understanding and interest in STEM content, skills, and careers on the part of K–12 students, a goal articulated in A Framework for Science Education (NRC 2012):

“...the overarching goal of our framework for K–12 science education is to ensure that by the end of 12th grade, all students have

some appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology. (p. 1)”

Given the research-based successes of the GK–12 approach, it makes perfect sense to implement that approach to improve postsecondary and K–12 education, foster scientific literacy, and train the next generation of STEM professionals.

FOR MORE INFORMATION

FOR MORE INFORMATION


- Thompson, S.L. 2003. Development of a framework to measure science teachers’ inquiry perceptions and practices. Paper presented at the annual meeting of the Association for the Education of Teachers of Science, St. Louis, MO.


APPENDICES

APPENDIX 2.1
SAMPLE TEACHER PARTNERSHIP APPLICATION/AGREEMENT

OVERVIEW
PRISM is a National Science Foundation Graduate Teaching Fellows in K–12 Education (NSF GK–12) project that awards 12-month Fellowships to eligible graduate students and K–12 Teachers. Each PRISM Teacher partners with a PRISM Fellow to develop and implement compelling, inquiry-based science lessons. Our Fellows are science or math Ph.D. students from Emory or Clark Atlanta University who are studying to become scientists/mathematicians, and college professors. Together, each Fellow–Teacher team attends a two-week Summer Institute to learn about problem-based learning (PBL) and investigative case-based learning (ICBL) pedagogy. You will spend time together at the Institute and over the summer developing original problems and cases, and adapting existing materials for use in your classroom. Your graduate student partner will assist you in implementing the cases in your class, spending an average of about 10 hrs/wk at your school (actual time spent in the classroom will typically fluctuate from week to week, but you will collaborate to make specific plans).

PRISM is an intense yearlong partnership with a graduate student and requires a significant commitment of time, including a two-week summer institute (June 6–17) and four planning days (one each in July, September, January, and June). Teacher participation also requires an average of 2 hrs/wk during the summer, fall and spring outside of class time to plan with your graduate student, develop and revise lessons, and complete monthly reports. Ultimately, you will gain significant practice in the development and implementation of problem-based learning lessons and you will publish your materials on CASES Online (http://www.cse.emory.edu/cases), sharing your work with educators around the world.

ELIGIBILITY
PRISM is open to science and mathematics Teachers in middle schools and high schools within Atlanta Public Schools, City Schools of Decatur, DeKalb County Schools, and Fulton County Schools. Previous experience with PBL is not required. Former PRISM Fellows are not eligible, but may apply for the PRISM/CFNM Fellowship (see FAQ below). Applicants must have the experience and skills to mentor a novice educator in classroom management and student assessment. Applicants must have permission of their principal to participate. We prefer applicants from schools that have other current applicants or former PRISM Fellows (i.e., a team of PRISM Teachers at the same school). Teachers who are participating in summer school or have other lasting summer obligations are strongly discouraged from applying because PRISM is so time-intensive.

AWARD INFORMATION
All PRISM Teachers receive a $4,000 stipend for full participation. The stipend is distributed in three payments: August 2011 (40%), December 2011 (30%), and May 2012 (30%). Failure to participate in project activities or meet the responsibilities listed in this document may result in an adjustment of stipend at the discretion of project administrators.

FREQUENTLY ASKED QUESTIONS
1. For what kind of Teacher is PRISM looking?
The PRISM Fellowship is ideal for Teachers who want to spend the time and energy to reflect on and improve their teaching practices. We are looking for critical eyes, innovative spirits, and open minds. We want Teachers who are willing to try student-centered teaching techniques that give more responsibility for learning to the student. We need Teachers who welcome the opportunity to work with a Fellow inside and outside the classroom. We want someone who is willing to mentor the Fellow in classroom management, lesson planning, and assessment of student learning. We want someone who will be available for all PRISM professional development days, and who will meet with his/her Fellow weekly throughout the summer, fall and spring to plan collaboratively. We prefer applicants from schools that have other current applicants or former PRISM Fellows (i.e., a team of PRISM Teachers at the same school).

IMPORTANT APPLICATION DATES
<table>
<thead>
<tr>
<th>Date</th>
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<tbody>
<tr>
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</tr>
<tr>
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</tr>
<tr>
<td>Apr 1, 2011</td>
<td>Award Notification</td>
</tr>
<tr>
<td>Apr 15, 2011</td>
<td>Deadline for Acceptance of Award</td>
</tr>
</tbody>
</table>

SOURCE: E M O R Y  U N I V E R S I T Y
2. In this partnership, what are the roles of the Teacher and the graduate student?
The Teacher will serve as a mentor to the Fellow with regard to teaching, curriculum planning, and classroom management. The Fellow will provide content expertise and serve as an enthusiastic role model of a young scientist/mathematician to your students. It is important to note that the PRIS M Fellow is not a student-Teacher nor a tutor. Fellows may or may not have had prior teaching experience, and they are not studying to become K–12 Teachers. PRIS M Fellows are enrolled in Ph.D. projects in a variety of science and mathematics disciplines (e.g. Chemistry, Biological Sciences, Mathematics, Physics, Psychology). They are participating in PRIS M to become better scientists and more confident professors by practicing and improving their teaching, communication, and research-dissemination skills.

3. How will the PRIS M Teacher Fellowship benefit me?
The PRIS M Teacher Fellowship will provide you with an opportunity to develop and implement innovative science and math lessons to engage your students in the science behind real world phenomena. Your students will become motivated investigators, self-directed and life-long learners, critical thinkers and keen problem-solvers. There is no one-size-fits-all solution to reach this goal, but PRIS M gives you the time, the training, and the resources (including your stipend, Fellow partner, and a professional learning community of other PRIS M Fellows) to develop what works best for you and your students. You will have the opportunity to present your work at regional conferences, publish your cases online and in scholarly journals, and lead your colleagues in implementing this exciting pedagogy. You will become a key component in the bridge we are building between K–12 schools and universities. In partnership with graduate students, faculty, and staff from Emory University and Clark Atlanta University, you will join a cadre of dedicated science educators who are transforming K–12, undergraduate, and graduate science education to ensure a scientifically literate public.

4. What is the PRIS M/CFNM Fellowship?
Chemistry and physics Teachers may also be interested in the PRIS M/CFNM Fellowship, which combines PRIS M with a 6-week summer research experience in nanoscience.

Overview: The PRIS M project has partnered with Clark Atlanta University’s Center for Functional Nanoscale Materials (CFNM), a National Science Foundation Center of Research Excellence in Science and Technology, to offer joint PRIS M/CFNM Teacher Fellowships in nanoscience research and problem-based learning curriculum development. PRIS M/CFNM Teachers participate in most components of the PRIS M project and in guided research experiences in Clark Atlanta’s nanoscience labs, and ultimately translate the CFNM’s nanoscience research into problem-based learning (PBL) curriculum materials.

The PRIS M/CFNM Teachers attend the 2-week PRIS M Summer Institute at Emory and work together to begin creating lessons on nanoscience topics. Teachers then spend the following six weeks in Clark Atlanta labs, working on a variety of nanoscience research projects alongside CFNM graduate students and faculty. Weekly seminars provide time to discuss and make presentations on various nanoscience topics including biosensors, nanotubes, nanofibers and the ethical use of nanotechnology. Teachers also complete weekly journals to document their lab experiences and to reflect on: a) their own personal and professional development through the project; b) how they might translate their experiences into meaningful learning experiences for their students; and c) their thoughts/concerns/ideas/hopes relevant to science education, nanoscience research, PBL, student engagement, curriculum development, etc. Teachers and graduate students meet weekly to discuss their experiences and to work together on PBL case development.

5. How is the PRIS M/CFNM Fellowship different from the regular PRIS M Fellowship?
PRIS M/CFNM Fellows do everything that PRIS M Fellows do with the following exceptions:

• PRIS M/CFNM Fellows attend a 6-week summer research experience at Clark Atlanta.
• PRIS M/CFNM Fellows create 4 of the 8 required PBL lessons on nanoscience and research topics.
• PRIS M/CFNM Fellows partner with Clark Atlanta graduate Fellows who work with them over the summer and during the school year for 5 hrs/wk (as opposed to 10 hrs/wk for regular PRIS M Graduate Fellows).
• PRIS M/CFNM Fellows receive an $8000 stipend, paid out in August (50%), December (25%), and May (25%).
• PRISM/CFNM Fellows receive an $800 supply budget to support nanoscience lessons in their classrooms.
• High School chemistry or physics Teachers (including former PRISM Teacher Fellows) and community college instructors are eligible for PRISM/CFNM Fellowships.

FOR MORE INFORMATION
Visit our website at http://www.prism.emory.edu. For questions about PRISM or the application process, contact John Doe at ###-###-#### or john.doe@uni.edu

APPLICATION PROCEDURE
Part A: Online Survey
Complete the survey available at http://www.prism.emory.edu/app/Teacher.cfm

Part B: Teacher Materials
1. Résumé or curriculum vitae
2. Written Statement - In a 2–4 page, double-spaced, typed statement, please include the following:
   a. What makes you a good PRISM applicant?
   b. Why you are interested in the PRISM Fellowship, how you will benefit from participation in PRISM, and how PRISM will benefit from your participation.
   c. Your experiences working with others in curriculum development or other educational projects, and your reflections on those experiences (i.e., what worked? what didn’t? how did/would you change it next time?).
   d. Any other information that might help us to choose you.
   e. Your name and school in the document header.

Assemble all Part B items together in a single DOC or DOCX file and email it to Jane Doe jdoe@email.edu. Name the file “YourlastnamePRISM11.doc” (e.g., my file would be called DoePRISM11.doc).

Part C: Letter of Support
1. Signed Cover Sheet
2. Letter of Support
Ask your principal to complete these materials and submit them directly to Jordan Rose at the Center for Science Education by the PRISM application deadline. The Cover Sheet must be signed by the applicant and the principal. The Cover Sheet is available at http://www.prism.emory.edu/app/Teacher.cfm.

All application materials must be received by 5pm on March 4, 2011. Applications are not considered complete until all parts have been received. Late applications will not be reviewed. Contact Jane Doe (###-###-####) to check on the status of your application.

FELLOWSHIP RESPONSIBILITIES AND ACTIVITIES
Overview:
• Mentor graduate student partner during curriculum development and classroom implementation of problems and cases.
• Meet weekly* with your graduate student partner outside of class time to develop cases, plan implementation, reflect and develop case notes, etc. (at least 1 hr/wk). *These meetings must be face-to-face meetings or phone conversations; emailing is not sufficient.
• Spend at least 1 hr/wk for independent work, including case preparation, completion of evaluation instruments, and monthly reflections (see below).
• Submit Monthly Progress Reports (2-page forms outlining work accomplished and reflecting on experiences).
• Develop, implement, and submit ≥8 Cases for publication on our CASES Online website, which serves as a resource to educators in Georgia and across the world.
• Attend one Reflection & Planning Session each semester with PRISM staff during planning periods or after school.
• Attend events listed below and additional project meetings as needed.
• Summer Institute. June 6–17, 2011. 8:30am–4:30pm.
• Summer Planning Day. July 29, 2011. 9am–4pm.
• Fall Planning Day. September 2011. 9am–4pm.
• Spring Planning Day. January 2012. 9am–4pm.
• Demo Day. June 2012. 9am–4pm.

Pre-Fellowship Events
• School visits. We will arrange for your Graduate Fellow partner to visit your school.
• Kickoff Picnic (date TBA). This is a social event that occurs prior to the official commencement of the Fellowship. Payment will not begin until summer 2011.
Summer Specifics:
• Attend the Summer Institute from 8:30am–4:30pm, Monday–Friday June 6–17, 2011. Some evening work is necessary (readings, team meetings, brief tasks).
• Meet weekly with Graduate Fellow to continue case development and planning.
• Develop Fall Implementation Plan outlining when and how cases will be implemented.
• Attend Summer Planning Day (July 29, 2011) and submit current versions of case materials.

Fall Specifics:
• Attend Fall Planning Day (September) and update Fall Implementation Plan.
• Develop Spring Implementation Plan outlining when and how cases will be implemented.
• Submit current versions of case materials (December).

Spring Specifics:
• Attend Spring Planning Day (January).
• Make 10-minute presentation giving a brief overview of cases implemented, example of successful case including student products, and reflections on the PRISM experience to faculty, school administrators, next year’s PRISM cohort, and guests at Demo Day (May/June).
• Submit final versions of case materials (May).

What you can expect from PRISM:
• Meals, beverages, and/or snacks at PRISM meetings, as appropriate.
• Support for classroom implementation of curricula, including additional facilitators, technical support, supplies, etc.
• Professional development in job application process, teaching philosophy development, etc.
• Feedback from PRISM staff on progress and materials.
• Stipend distributed in August 2011 (40%), December 2011 (30%), and May 2012 (30%).
APPENDIX 3.1
APPLICATION FOR GK-12 FELLOW
GEORGIA TECH STUDENT AND TEACHER ENHANCEMENT PARTNERSHIP (GT-STEP)

Applicant (print name) ________________________________________________________________

E-mail address _____________________________ Phone _________________________________

Anticipated Final Degree _____________________________________________________________

Date began Graduate School at GT ____________________________________________________

Please check one:  ☐ US Citizen  ☐ US National  ☐ US Permanent Resident

Home School/Department ______________________

Major ______________________________________

Advisor _____________________________________

Advisor’s Home School/Department ____________

Expected Term for Degree Completion __________

Undergraduate Degree _________________________

Undergraduate institution ___________________________________________________________________

In what section of the Atlanta area do you now live?  
(This will not affect your chance of placement in the project—it is just used for school assignment purposes.)

________________________________________________________________________________________

Briefly state why you want to be a STEP K–12 Fellow.

________________________________________________________________________________________

________________________________________________________________________________________

________________________________________________________________________________________

________________________________________________________________________________________

________________________________________________________________________________________

________________________________________________________________________________________

________________________________________________________________________________________

________________________________________________________________________________________

________________________________________________________________________________________

SOURCE: GEORGIA TECH UNIVERSITY
APPENDIX 3.2

GK–12 FELLOW APPLICATION
UNIVERSITY OF IDAHO WATERS OF THE WEST

Copy and paste this document into a word processor and complete. Then email it as an attachment to the GK–12 project manager John Doe at doe@univ.edu. Provide as much information as you want. Please attach a current short resume along with the completed application. Thanks for your interest.

Name: ____________________________________________________________
Department: _________________________________________________________

Are you a participant in Waters of the West “Water Resources”, Environmental Science, or Environmental Engineering projects? Yes ☐ No ☐ (if yes, please indicate which one)
__________________________________________________________________________

Degree seeking: MA ☐ MS ☐ PhD ☐
Year in degree project: (as of Fall 2012) ________________________________

Have you talked with your faculty advisor about your possible participation in the project? Yes ☐ No ☐

Who is your faculty advisor? _____________________________________________

Your undergraduate degree (include area of emphasis if applicable): ______________

Your MS degree (if applicable): ____________________________________________

Your current research topic (if applicable): _________________________________

Contact information for applicant: _________________________________________

Email: _______________________________________________________________

Phone: _____________________________

Briefly explain why you are interested in participating in this project. What insights, ideas, expertise, and passion are you contributing to the project? What do you hope to gain from the experience? A paragraph is sufficient, but candidates often write more.

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________
OVERVIEW
PRISM is a National Science Foundation Graduate Teaching Fellows in K–12 Education (NSF GK–12) project that awards 12-month Fellowships to eligible graduate students. Each PRISM Graduate Fellow partners with a middle or high school Teacher to develop and implement compelling, inquiry-based science lessons. Fellows and Teachers participate in a two-week Summer Institute on problem-based learning (PBL) and investigative case-based learning (ICBL) pedagogy. Together, each Teacher–graduate student team spends the summer writing original problems and cases and planning for classroom implementation the following school year. Graduate Fellows spend approximately 12 hrs/wk during summer, fall, and spring, participating in PRISM activities including case development and implementation, planning, evaluation, and reflective teaching practices. This time will include approximately 10 hrs/wk in the K–12 classroom. Days actually spent in the classroom will vary according to placement, and Fellows may not be in the classroom every week. Participation in PRISM requires a time commitment that typically fluctuates from week to week, but will average 12 hrs/wk, and include a two-week summer institute (June 6–17) and four planning days (one each in July, September, January, and June). More details below.

IMPORTANT APPLICATION DATES

<table>
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<tr>
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</tr>
</tbody>
</table>

ELIGIBILITY
PRISM is open to doctoral students in the following projects and departments: Emory’s Anthropology, Behavioral Sciences and Health Education, Biomedical Engineering, Biostatistics, Chemistry, Epidemiology, all Graduate Division of Biological and Biomedical Sciences projects, Mathematics, Physics, Psychology; and Clark Atlanta’s Chemistry and Biology projects. Previous experience in K–12 classrooms is not required. Applicants must:
- be full-time students in good standing in their graduate project
- have permission of their mentor to participate
- NOT be enrolled in any courses during the Fellowship year
- NOT participate in any teaching assistantships during the Fellowship year

All Fellows are expected to devote themselves full time to their PRISM and research activities during the Fellowship year and hence may not undertake other coursework or teaching opportunities, without approval from PRISM administrators. Emory Fellows who receive offers for other awards should contact the Graduate School and PRISM to determine whether the two awards may be held concurrently.

AWARD INFORMATION
All PRISM Graduate Fellows receive a $30,000 stipend* plus an allowance for tuition, fees, and health insurance. Failure to participate in project activities or meet the responsibilities listed in this document may result in an adjustment of stipend at the discretion of project administrators.

* Stipends for Emory PRISM Fellows are compiled from multiple sources (see table below), including Emory’s National Science Foundation (NSF) Graduate Teaching Fellows in K–12 Education (GK–12) grant, Emory’s Office of the Provost, the Emory Graduate School, and a contribution from the graduate students’ faculty mentor, department, or other sources that would permit the students’ participation in the PRISM project. The Emory Graduate School will receive approximately $4,666 in tuition, fees, and health insurance for each Fellow.

<table>
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<th>SOURCES OF EMMORY PRISM FELLOW STIPEND</th>
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<tr>
<td>PRISM Award (NSF &amp; Emory Sources)</td>
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</tr>
<tr>
<td>Mentor/Dept. Contribution</td>
<td>$11,500</td>
</tr>
<tr>
<td>Total Stipend</td>
<td>$30,000</td>
</tr>
</tbody>
</table>

One PRISM Fellow each year will be selected from doctoral students in biology and chemistry at Clark Atlanta University. The stipend for the Clark Atlanta
Fellow comes from our NSF GK–12 project subaward to Clark Atlanta and will be paid to the Fellow through Clark Atlanta. The subaward includes an allowance of $10,500 for tuition, fees, and health insurance.

FOR MORE INFORMATION
For questions about PRISM or the application process, contact John Doe at ###-###-#### or john.doe@univ.edu

APPLICATION PROCEDURE

Part A: Online Survey
Complete the survey available at http://www.prism.emory.edu/app/grad.cfm

Part B: Student Materials
1. Emory Graduate School Fellowships Application Cover Sheet
2. Curriculum vitae
3. Written Statement - In a 2–4 page, double-spaced, typed statement, please address the following:
   a. Why you are interested in the PRISM Fellowship, how you will benefit from participation in PRISM, and how PRISM will benefit from your participation.
   b. Preferred K–12 grade level and subject (e.g., high school chemistry, middle school physical science).
   c. In 1–2 paragraphs, illustrate one way you might use an active learning method to teach a specific science concept for the grade level and area chosen above.
   d. In a single paragraph, explain your research (current and/or future) as if you were speaking to a typical high school student.
   e. Brief statement of any prior experience and interest in working with K–12 Teachers or students. This could include volunteer work, tutoring, or other experience. (NOTE: prior experience is NOT required - if you have little experience, emphasize your interests and rationale for applying).
   f. Brief statement of science background (baccalaureate and post-baccalaureate coursework, research, or other experience) and teaching experience (if any).

Assemble all Part B items together in a single PDF file and email it to Jane Doe at jdoe@email.edu. Name the file “YourlastnamePRISM11.pdf”. Download the Cover Sheet and guidance on creating PDF files from the right-hand margin of http://www.gs.emory.edu/resources/financial.php?entity_id=18
You may also use the Woodruff Library or other office to scan and email the file as a PDF.

Part C: Mentor Support Materials
1. Signed Cover Sheet
2. Letter of Support
Ask your faculty advisor/research mentor to complete these materials (Cover Sheet available at http://www.prism.emory.edu/app/grad.cfm) and submit them to Jane Doe at the Center for Science Education.
All application materials must be received by 5pm on March 4, 2011.

FELLOWSHIP RESPONSIBILITIES AND ACTIVITIES

Overview:
• Graduate Fellows should spend an average of 12 hrs/wk on PRISM activities:
  – Spend approximately 10 hrs/wk planning, developing, and implementing problems and cases with K–12 Teacher partner. During the school year, Graduate Fellows should spend no more than 10 hrs/wk in the K–12 classroom.
  – Spend approximately 2 hrs/wk for independent work, including readings, case preparation and research, completion of evaluation instruments and progress reports (see below).
• Meet weekly with your K–12 Teacher partner (face-to-face or by phone).
• Submit Monthly Progress Reports (2-page forms outlining work accomplished and reflecting on experiences).
• Develop, implement, and submit Case Materials for publication on our CASES Online website, which serves as a resource to educators in Georgia and across the world.
• Attend Reflection Sessions every other week with PRISM staff (a regular time will be coordinated to best fit everyone’s schedules).
• Attend events listed below and additional project meetings as needed.
  – Summer Institute. June 6–17, 2011. 8:30am–4:30pm.
  – Summer Planning Day. July 29, 2011. 9am–4pm.
Pre-Fellowship Events

- School visits. We will arrange for you to visit your Teacher-partner’s school.
- Kickoff Picnic (date TBA). This is a social event that occurs prior to the official commencement of the Fellowship. Payment will not begin until June 2011.

Summer Specifics:

- Attend the Summer Institute from 8:30am–4:30pm, Monday–Friday June 6–17, 2011. Some evening work is necessary (readings, team meetings, brief tasks).
- Meet weekly with K–12 Teacher partner to continue case development and planning.
- Develop Fall Implementation Plan outlining when and how cases will be implemented.
- Attend Summer Planning Day (July 29, 2011) and submit current versions of case materials.

Fall Specifics:

- Attend Fall Planning Day (September) and update Fall Implementation Plan.
- Develop Spring Implementation Plan outlining when and how cases will be implemented.
- Submit current versions of case materials (December).

Spring Specifics:

- Attend Spring Planning Day (January).
- Make 10-minute presentation giving a brief overview of cases implemented, example of successful case including student products, and reflections on the PRISM experience to faculty, school administrators, next year’s PRISM cohort, and guests at Demo Day (May/June).
- Submit final versions of case materials (May).

What you can expect from PRISM:

- Meals, beverages, and/or snacks at PRISM meetings, as appropriate.
- Support for classroom implementation of curricula, including additional facilitators, technical support, supplies, etc.
- Professional development in job application process, teaching philosophy development, etc.
- Feedback from PRISM staff on progress and materials.
- PRISM stipend distributed in equal monthly installments from June 2011 through May 2012.
### APPENDIX 4.1
### SAMPLE GK–12 PROJECT RESOURCES

<table>
<thead>
<tr>
<th>Description</th>
<th>For Further Information</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GK–12 WORKSHOPS, INSTITUTES, AND COURSES</strong></td>
<td></td>
</tr>
<tr>
<td>Course in teaching methods for science graduate students</td>
<td>Baumgartner 2007</td>
</tr>
<tr>
<td>Integrating pedagogical training into the graduate project</td>
<td>Tanner and Allen 2006</td>
</tr>
<tr>
<td>Example of a GK–12 partnership training model</td>
<td>Stamp and O’Brien 2005</td>
</tr>
<tr>
<td>Integrating teaching and research for graduate students</td>
<td>Trautmann and Krasny 2006</td>
</tr>
<tr>
<td><strong>SCIENCE PARTNERSHIP PROJECTS</strong></td>
<td></td>
</tr>
<tr>
<td>Assessment of Teacher–scientist partnership related to wind energy</td>
<td>Caton et al. 2000</td>
</tr>
<tr>
<td>GK–12 partnership model focused on ecology</td>
<td>McBride et al. 2011</td>
</tr>
<tr>
<td>Project SERVE: reflections on the experience of scientists in the K–12 classroom</td>
<td>Gilmer et al. 2005</td>
</tr>
<tr>
<td><strong>EXAMPLES OF CURRICULA AND TEACHING STRATEGIES</strong></td>
<td></td>
</tr>
<tr>
<td>Peer Perspectives Volume II: A Novel Approach to Quality GK–12 Interactions</td>
<td>Sanchez et al. 2010</td>
</tr>
<tr>
<td>Problem-based learning “how-to” guide</td>
<td>Duch et al. 2001</td>
</tr>
<tr>
<td>Problem Based Learning Clearinghouse</td>
<td>University of Delaware 2012</td>
</tr>
<tr>
<td>Handbook for Culturally Responsive Science Curriculum</td>
<td>Stephens 2003</td>
</tr>
<tr>
<td>Using inquiry to improve pedagogy through K–12/university partnerships</td>
<td>Huziak-Clark 2007</td>
</tr>
<tr>
<td>Discussion on achieving scientific literacy</td>
<td>Bybee 1997a and b</td>
</tr>
<tr>
<td>Using concept maps in instruction</td>
<td>Novak 1998</td>
</tr>
<tr>
<td>Using the 5E model in teaching</td>
<td>Tanner 2010</td>
</tr>
<tr>
<td>Teaching in the elementary school science classroom</td>
<td>Beichner and Dobey 1994</td>
</tr>
<tr>
<td>A scientific approach to curriculum development and assessment</td>
<td>Handelsman et al. 2007</td>
</tr>
<tr>
<td><strong>ASSESSMENT AND REFLECTIVE PRACTICE TOOLS AND APPROACHES</strong></td>
<td></td>
</tr>
<tr>
<td>Using rubrics as tools for making learning goals and evaluation criteria explicit</td>
<td>Allen and Tanner 2006</td>
</tr>
<tr>
<td>Review of assessment practices and theory in the areas of assisting learning, individual achievement, and project evaluation</td>
<td>NRC 2001</td>
</tr>
<tr>
<td><strong>LEARNING THEORY</strong></td>
<td></td>
</tr>
<tr>
<td>How people learn from infancy through adulthood</td>
<td>Eshel 2007</td>
</tr>
<tr>
<td>Theory and practice on how people learn</td>
<td>NRC 2000</td>
</tr>
</tbody>
</table>
APPENDIX 4.2

CONTRACT BETWEEN THE UNIVERSITY OF MONTANA AND THE GK-12 FELLOW

This Contract confirms the understanding between the University of Montana (herein called UM) and GK12 Fellows selected to participate in the ECOS Project.

1. Scope of Work. Duties and responsibilities of PhD Fellows, as outlined in the grant funded by the National Science Foundation, are attached. NOTE: Montana law requires that all regular volunteers and Teachers undergo a criminal background check before they can work in academic institutions. The ECOS project will coordinate and pay for this background check.

2. Period of Project. The period of work covered by this agreement shall begin on ___________ and shall terminate on ____________.

3. Fiscal Arrangements. UM agrees to pay the GK12 Fellows $ __________ for 12 months (divided into 12 equal payments) provided that the Fellow has completed the work requirements and required hours for the month. Checks will be mailed to the Fellow’s mailing address. UM also agrees to pay tuition and fees of up to $ __________ for the academic year (not including the summer session). In the unusual circumstance that a Fellow cannot continue participation in project activities, monthly payments will be prorated to cover only such time as the Fellow met the ECOS Project requirements.

4. Meeting Obligations of the Fellowship. If the ECOS staff, partner Teachers, or graduate advisor has concerns that a Fellow is not fulfilling the required obligations for his or her work as a Fellow or graduate student, the ECOS Director, ____________, will be notified. S/he, or a designee, will work with the Fellow to clarify expectations and develop a plan for remediation. If the problem is not corrected, the Fellow’s academic advisor will be contacted for a conference with the director and Fellow to determine an appropriate course of action. If the Fellow still cannot meet project obligations, his or her Fellowship may be terminated.

5. Conditions That May Lead to Early Termination. This agreement can be terminated upon two weeks’ written notice by the Director if a Fellow fails to comply with project requirements. Fellows may be terminated immediately for illegal activities conducted at a school site or that involve minors. Fellows may terminate participation in the ECOS Project with two weeks’ written notice to the Director. However, payment of the stipend will terminate at that time.

I have read about and agree to the duties and responsibilities listed in these documents:

ECOS PhD Fellow Signature: _________________________________ Date: ______________

Director/PI Signature: _________________________________ Date: ______________

PhD Advisor Signature: _________________________________ Date: ______________

Committee Members Signatures: _________________________________ Date: ______________

SOURCE: UNIVERSITY OF MONTANA
ECOS Project PhD Fellows’ Duties and Responsibilities

The duties and responsibilities of ECOS Fellows are summarized below. Support of the advisor and Committee is required for the listed duties (advisors and Fellows sign the attached agreement and initial each page). This Fellowship is intended to support Fellows, much like having a TA or RA, as they make good progress toward degree requirements. Because of the potentially negative influence on making progress toward graduation, the ECOS project leaders discourage Fellows from holding additional positions in addition to this Fellowship.

1. Fellows are ambassadors of the University of Montana. As such, Fellows are expected to dress in accordance with professional standards at the school, and interact in a respectful manner with partner Teachers, school staff, and students.

2. Fellows are expected to meet all deadlines for project and information gathering activities. When delays cannot be avoided, Fellows are expected to notify the ECOS staff and negotiate a new deadline. Failure to participate in reporting may lead to an early termination of the Fellowship.

3. Project activities begin on ______. Summer activities will include developing a plan for the ______ academic year. The Fellowship ends _______.

4. PhD Fellows are required to write a chapter in their Dissertation about the ECOS Fellowship outcomes and experience, and to submit a manuscript from this chapter for publication in an appropriate teaching journal. Time spent working on this chapter is considered part of the dissertation research and may NOT be counted toward the 15 hour work requirement of the ECOS Fellowship.

5. Fellows will all work together as a team of two graduate students and two Teachers. Fellows are expected to work on ECOS activities for 15 hours per week during the Fellowship. This obligation is met through a combination of planning time, research and investigation planning, and working with Teachers in their classrooms.

6. The lead Teacher(s) and Fellows will work in partnership in the schools. During the school year, the Fellows will rotate their activities between different schools and classrooms, according to the needs they identify during weekly planning.

7. According to Montana law, a Teacher must be present in the classroom whenever the Fellow is in the classroom. The Teacher will guide the Fellow’s interactions with students in the classroom, and provide him or her constructive and timely feedback. Teachers are responsible for all classroom discipline.

8. The Fellow must provide one reliable form of contact that he or she will check on a daily basis (email, home phone number, school phone number, cell phone number) to the ECOS Director and Team Fellows.

9. Fellows will be required to take BIO/FOR 595 for 1 credit per semester. This time will be used for coordination with ECOS leaders and for “whole project” planning.

10. The Fellow will work with other ECOS Fellows and lead Teachers to present workshops for scientists and/or Teachers at meetings and conferences as appropriate (e.g., ESA, MSTA, etc.). He or she will also work together to create newsletters, inquiries, and other materials to disseminate and plan for project sustainability. This will be an important activity during this academic year.

11. The Fellow will complete and deliver assessment instruments and/or participate in interviews as part of project evaluation.
### APPENDIX 4.3

**SAMPLE ADVISOR FEEDBACK SURVEY TOOL**

As an advisor of a graduate student who received a Fellowship, we would like to get your feedback on the benefits and drawbacks of having your student participate in this Fellow–Teacher–school partnership project.

1. Please rate the following potential benefits of the Fellowship:

<table>
<thead>
<tr>
<th>Benefit</th>
<th>A major benefit</th>
<th>A minor benefit</th>
<th>Not a benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provided student with valuable teaching experience</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provided student with valuable community service experience</td>
<td></td>
<td></td>
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<tr>
<td>Provided financial support for student</td>
<td></td>
<td></td>
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<tr>
<td>Provided student with opportunity to do research for a dissertation chapter</td>
<td></td>
<td></td>
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<tr>
<td>Other (please describe):</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

2. Please rate the following potential drawbacks of the Fellowship:

<table>
<thead>
<tr>
<th>Drawback</th>
<th>A major drawback</th>
<th>A minor drawback</th>
<th>Not a drawback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required student to take time away from dissertation</td>
<td></td>
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<tr>
<td>Required student to take time away from other research responsibilities</td>
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<td></td>
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<tr>
<td>Required student to spend time on activities not related to their discipline</td>
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<td></td>
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<tr>
<td>Other (please describe):</td>
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</tbody>
</table>

3. Would you recommend another of your students for a Fellowship?  □ Yes  □ No

4. What other comments or suggestions do you have about the Project and Fellowships?

Please feel free to add additional pages as needed.

SOURCE: UNIVERSITY OF MONTANA
APPENDIX 4.4

UNIVERSITY OF MONTANA SAMPLE CURRICULUM UNIT TEMPLATE

To use this template, fill in the required information for each element after the colon. You may wish to cut and paste information from another file. Feel free to insert diagrams as necessary (be sure to provide a reference for any diagrams created by other people).

1. Contributors’ Names:

2. Name of Unit/Investigation:

3. Goals and Objectives:
   a. Inquiry Questions:
   b. Science Theme(s):
   c. General Goal:
   d. Specific Objectives:
   e. Grade Level:
   f. Duration/Time Required:
      __ Prep time
      __ Implementing Exercise During Class
      __ Assessment

4. Science Context:
   a. Background (for Teachers):
   b. Background (to present to Students):

5. Motivation and Incentive for Learning

6. Vocabulary:

7. Safety Information:

8. Materials List (including any handouts or transparency masters):

9. Methods/Procedure for students:
   a. Pre-investigation work:
   b. Investigation work:
      1) What evidence (data, samples) do students collect?
      2) How do students present the evidence (data)?
      3) What conclusions are drawn from the evidence students collect?
      4) Include examples of data sheets.

10. Assessment:

11. Extension Ideas:

12. Scalability

13. References:

14. List of Experts and Consultants

15. Evaluation/Reflection by Fellows and Teachers of how it went:

SOURCE: UNIVERSITY OF MONTANA
## APPENDIX 4.5
### GK–12 PEER OBSERVATION FEEDBACK TOOL

<table>
<thead>
<tr>
<th>GK–12 TEAM INSTRUCTION PEER OBSERVATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>GK–12 Team: __________________________</td>
</tr>
<tr>
<td>Peer Observer: _________________________</td>
</tr>
<tr>
<td>Date of Review: ________________________</td>
</tr>
</tbody>
</table>

### CONTENT AND SKILLS

<table>
<thead>
<tr>
<th>Question</th>
<th>Very Evident</th>
<th>Somewhat Evident</th>
<th>Somewhat Lacking</th>
<th>Not Evident at All</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Were students given an overview of the topic prior to the teaching session?</td>
<td></td>
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</tr>
<tr>
<td>2. Was the significance/importance of information to be learned provided?</td>
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<tr>
<td>3. Did the content link to previous instruction, building on previous skills and knowledge?</td>
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<tr>
<td>4. Was the unit illustrated with real life examples, models, and/or analogies?</td>
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<tr>
<td>5. Were students given time to assimilate the new skills and knowledge during the instructional period?</td>
<td></td>
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</tbody>
</table>

### DELIVERY

<table>
<thead>
<tr>
<th>Question</th>
<th>Very Evident</th>
<th>Somewhat Evident</th>
<th>Somewhat Lacking</th>
<th>Not Evident at All</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Was the session well organized?</td>
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<tr>
<td>7. Was there evidence of active, hands-on student learning?</td>
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<tr>
<td>8. Was the presentation made at an appropriate pace, stopping to check student understanding and engagement?</td>
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<tr>
<td>9. Were instructional aids (e.g., visuals, props, handouts, equipment) prepared and appropriate?</td>
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<tr>
<td>10. Were students given time to ask questions and clarify the new skills and knowledge they were developing?</td>
<td></td>
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<td></td>
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<tr>
<td>11. Were students treated respectfully?</td>
<td></td>
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</table>

### STUDENT ENGAGEMENT

<table>
<thead>
<tr>
<th>Question</th>
<th>Very Evident</th>
<th>Somewhat Evident</th>
<th>Somewhat Lacking</th>
<th>Not Evident at All</th>
</tr>
</thead>
<tbody>
<tr>
<td>12. Was there evidence of students actively listening and participating?</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>13. Was there evidence of students being passive or inattentive?</td>
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<tr>
<td>14. Were a variety of instructional strategies used to keep students attentive and involved?</td>
<td></td>
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<tr>
<td>15. Did the instructor(s) hold the attention and respect of students and practice effective classroom management?</td>
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</tbody>
</table>

### INTEGRATION WITH RESEARCH

<table>
<thead>
<tr>
<th>Question</th>
<th>Very Evident</th>
<th>Somewhat Evident</th>
<th>Somewhat Lacking</th>
<th>Not Evident at All</th>
</tr>
</thead>
<tbody>
<tr>
<td>16. Were examples of graduate student STEM research included to illustrate the application of skills and knowledge?</td>
<td></td>
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<tr>
<td>17. Were specific potential research topics/questions identified within the skill and knowledge contexts of the unit?</td>
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<tr>
<td>18. Were students specifically encouraged to further explore the skills and knowledge they were learning/gaining?</td>
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</tbody>
</table>

Strengths: What were the strengths of the instruction and unit?

Weaknesses: How can the instruction and unit be further enhanced?

Source: University of Montana
APPENDIX 5.1

GK–12 BEST PRACTICES AND POTENTIAL PITFALLS (OR.... HOW TO AVOID THE LATTER SO YOU CAN HAVE MORE OF THE FORMER)

Session Objective
Identify common pitfalls or roadblocks on the road to a successful GK–12 project and share ideas to avoid or solve problems that arise.

Session Leaders:
Carol Brewer and Dave Oberbillig (Univ of Montana ECOS GK–12 project), facilitated by Kevin Swanson, NSF GK–12 Einstein Fellow.

Carol and Dave started the session with a team-told story that embodied the evolution of their own project, some of the unexpected challenges they ran into in having their Fellows fully utilized by cooperating teachers and how the quiet perseverance and professionalism of individual Fellows won the teachers over.

The 45 session participants were individuals with different roles in their respective GK–12 projects. The format of the session was to break into working groups of 5–6 people, with participants from one GK–12 project dispersing into separate groups. Each group selected a scribe (to capture all ideas that were articulated and complete the group handout), poster maker (to create a poster of pitfalls encountered and navigational strategies to share) and a spokesperson (to moderate the group, bring consensus and report out the small group’s story to the large group).

The Discussion Decree given to the small groups was to identify:

1. Pitfalls – the 2 most common across projects and the 1 most unusual “out of nowhere” surprise; and
2. Strategies for Success – 2 that can be generalized to GK–12 projects and 1 most unique idea.

The reporting-out comments from the individual groups are summarized here in the section titled “GK–12 Lore: If I only knew then....” and information recorded by the groups is tabulated under the column headings Consensus Pitfalls and Success Strategies. A reflective summary section is included below the table. While no template for success exists that will encompass the varied nature of GK–12 projects, it is hoped that this document provides a resource that can help new projects anticipate and proactively plan for some of the operational challenges that inevitably arise during the life cycle of a GK–12 project.

The most common themes for “pitfalls” related to communication across the project organization, establishing boundaries and expectations for Teachers and Fellows, identifying appropriate matches between Fellows and cooperating Teachers, coordination of project activities, time management for participants (especially Fellows), teaching skills/concepts at an age appropriate level, problematic actions by some school administrators, cultural differences (K–12 and university) and sustainability.

Common ideas for success strategies included designing effective training for Fellows and Teachers, creating strong professional partnerships between Fellows and Teachers, clear communication, designing engaging learning activities, using technology effectively, providing professional development credit to facilitate “buy-in” from teachers, using written contracts to define and clarify respective roles and responsibilities for Teachers and Fellows, using follow-up workshops through the school year for Fellows and Teachers, Fellows making videos about their own research to show the students, utilizing Fellows with teaching experience to inform the program, requiring research advisors to share the experience of their Fellow and increasing attendance at meetings by offering food.

Some of the surprises reported while working with K–12 schools were the need to have Fellows fingerprinted for background checks, dealing with emergency evacuations of schools, a “dangling” Fellow who found himself without a class when the scheduled class was dissolved, and that Fellows shouldn’t be left alone (without a licensed teacher) in the classroom with the students.

The following section attempts to capture the themes emerging from the final reporting out from the small groups to the large group.

SOURCE: TRANSCRIPTION OF “BEST PRACTICES AND PITFALLS” WORKSHOP, 2008 GK–12 ANNUAL MEETING
GK-12 Lore: If I only knew then that . . . .

- Communication is essential and sometimes breaks down; (Was what it I think I said; what he/she thought she/he heard?)
- I have to get them together once in a while [Fellows, Fellows and Teachers] and feeding them really helps.
- Fellows and Teachers like free food–feed them and they will come.
- Others might have expectations that are different than mine.
- Other’s goals may not be my/our goals.
- Things besides lessons happen in schools (e.g. fire drills, lockdowns, TB shots and fingerprinting for Fellows).
- SOMEONE needs to coordinate everything, even the little things.
- I can’t fit all the science equipment in my car trunk (by a Fellow trying to bring equipment to use at a school, because there was very little at the school).
- Running things would take so much time.
- K–12 students work from different levels.
- Schools have standardized tests (which might significantly affect what learning activities can be implemented).
- Dangling Fellows need rescuing (Fellow was left dangling without cooperating Teacher due to changes at the school).
- School administrators may “forget” to follow through and might stop talking to us (or returning e-mails).
- Tuition-free college credits look like free chocolate to teachers (i.e. college course credits for work related to GK–12 activities are translated into additional salary compensation from the district to the teachers; designing project training and development activities so that cooperating teachers can earn tuition-free credit might increase their stake in the project and entice them to contribute additional thought, effort and creativity to their participation).
- Teachers may see the Fellow’s classroom role differently than the project management team does (and I need to take steps to make sure everybody is on the same page in this regard to help ensure a positive experience for participants).
- Research advisors are good arm wrestlers and some have a tendency to arm-wrestle for a Fellow’s time.
- Researchers are from Venus and Teachers are from Mars (i.e. we come from different personal cultures and I will need to keep this in mind to achieve the results I want).
- GK–12 Fellows are from Venus and research advisors are from Jupiter (i.e. potentially conflicting goals and expectations need to be understood).
- Gravity acts in stairwells (by a Fellow in a school where a Teacher was pushed down the stairs by a student–the project needs to be aware of the disturbing realities in some of the schools).
- Maybe I should share ownership of parts of this project.
- Some graduate students will be better fits as GK–12 Fellows than others.
- “Getting to know you” takes time (i.e. the first day of school is way too late for Fellows to meet their cooperating teachers).
- “Communicate” means different things.
- Written documents are important.
- Communication is affected by the trust of the community (of project participants).
- “Bull” happens and some people are better at drilling through it than others.
- People have different personalities.
- It is not easy to write a good people-to-people contract.
- Humans are fallible, flawed creatures that create messes to clean up (this wasn’t said verbatim but is a synopsis of the overarching context of some of the spontaneous discussion remarks generated during the reporting out from working groups to the larger group).
- If you’re not falling down once-in-a-while you’re not learning to ski better. Consider risk–reward balance and be willing to try things like having students collect rattlesnakes (really, it was reported that one Teacher was willing to have her students try this with snakes. NSF does not promote or endorse rattlesnake collecting by K–12 students. The projects are responsible for evaluating what is reasonable risk, but you get the idea).
- The GK–12 web site should be a resource for stuff (like contracts).
- Not all Teachers will perceive this (my) project as the best thing since sliced bread.
Session participants displayed significant energy around the topic of communication. Perspectives about what communication should look like:

- It’s a 2-way street; or more like a communication web between all the project participants;
- It should be early, often, consistent and appropriate. (How often was a point of some debate. Frequency of communication meetings needs to be balanced with other time demands. Frequent meetings just to meet without perceived value-added by meeting time can be frustrating.)
- Consistency of communication was perceived as essential to support project success. One Fellow indicated receiving conflicting answers to a question from the PI and the project manager.
- Participants felt that there needs to be a clear chain of command in the project to ensure consistency of communication. They suggested that project management needs to have a “communication hub” – someone designated as a point of contact to go to with operational questions and that there needs to be one person who “knows where everything is” in the project.

Individual Small-Group Newsprint Synopses

In the table on the following page, bold items are those identified by groups as the unique SHOCKER (or “super Pitfall” as described by some groups) or UNIQUE strategy (not all groups identified one).

Summary Comments:

Challenges in K–12 education may look different to those working outside “the K–12 system” than to those working inside. Many GK–12 Fellows report a transformation in their perception of what K–12 education looks like and the challenges within the system after they have worked in the schools with the Teachers and students. Many GK–12 project senior personnel (STEM researchers) may not initially have a deep familiarity with the day-to-day K–12 school schedule structure and other non-curricular operational and liability elements that are associated with being legally responsible for large numbers of minors. Given this situation and cultural differences between research worlds and K–12 education worlds, it is important that GK–12 project management attempt to listen carefully for concerns which Teachers and other school personnel may express and be prepared to adjust where needed to increase the probability of success.

It was apparent during the session that the most common recurring issue was the importance of building a positive and collaborative working relationship between the Fellow and cooperating Teacher, especially in those projects which use a one Fellow–one Teacher pairing model. Building this relationship, the filter through which the work of the Fellow with the K–12 students occurs, takes time and intentionality on the part of the project management and an understanding that GK–12 projects bridge different cultures that speak different languages. Clarifying expectations, defining respective roles and responsibilities in the classroom and creating a sense that the Fellow and Teacher are equal project stakeholders with different areas of expertise helps foster a positive working environment that increases the quality of the project experience and professional growth for both the Fellow and Teacher. It also lays the groundwork for positive benefits to the K–12 students.

The above transcribed lore and articulation of potential pitfalls and success strategies represent the collective experiential wisdom of 45 GK–12 participants from multiple projects from across the United States, as brainstormed and shared during one Annual Program meeting breakout session. It does not constitute a final recipe that can be transferred to each and every individual GK–12 project. However, it is hoped that it will help provide a “heads up” for oncoming potholes and detours as well as potential strategies to help GK–12 project management navigate down their own GK–12 highway.

Transcribed by Kevin Swanson 2007-08 Albert Einstein Distinguished Educator Fellow assigned to NSF GK–12 Program.
<table>
<thead>
<tr>
<th>Consensus Pitfalls</th>
<th>Success Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>· Unresponsive school administrators and lack of coordination with school administration</td>
<td>· Create teacher “buy-in” through paid credits for teachers during the program planning process</td>
</tr>
<tr>
<td>· Lack of clarity about roles and allowing assumptions to lead the way</td>
<td>· Contracts between constituents and open communication</td>
</tr>
<tr>
<td>· Balancing GK–12 time with research – while meeting all expectations</td>
<td>· Require research advisors to share experience with their Fellows</td>
</tr>
<tr>
<td>· Communication, communication, communication</td>
<td></td>
</tr>
<tr>
<td>· Clarity of roles not always explicit</td>
<td>· Articulating boundaries/roles across levels</td>
</tr>
<tr>
<td>· Breakdown in communication both within and across levels (PI’s, Fellows, Teachers)</td>
<td>· Feed the Fellows (and teachers too) and they will come [to the project meetings]</td>
</tr>
<tr>
<td>· Interference from high stakes testing and unforeseen complications in the schools</td>
<td></td>
</tr>
<tr>
<td>· Thinking what we proposed was actually what we were going to do!</td>
<td>· extend deadlines (for applications) to increase pool of [Fellow] applicants (but be careful...)</td>
</tr>
<tr>
<td>· Cultural differences</td>
<td>· Bring back your best Fellows ... even though it’s best to share the love</td>
</tr>
<tr>
<td>· Don’t give all the $5 out at summer workshop</td>
<td></td>
</tr>
<tr>
<td>· Lack of understanding of roles and expectations (and lack of prior knowledge of each other), i.e. what a “middle schooler” was like and what a graduate student is</td>
<td>· Make clear roles and expectations = communication = “job descriptions” in writing - contract with Fellows and teachers (co-ownership to define roles)</td>
</tr>
<tr>
<td>· Bureaucracy – school districts/administration, schools, university, classrooms (difficulty with field trips)</td>
<td>· Formal Application and Interview process = in person to assess accurately (not clear if this was referring to Fellows, teachers or both)</td>
</tr>
<tr>
<td>· Teacher leaves due to injury, no substitute, class is dissolved and students spread out to other classes = no classroom classes for Fellow – what do you do?</td>
<td>· Bring back at least 2 fellows to help train new Fellows (use your best options)</td>
</tr>
<tr>
<td>· Sustainability</td>
<td>· Planning prior to the school year</td>
</tr>
<tr>
<td>· Lack of coordination (at all levels)</td>
<td>· Hands-on activities</td>
</tr>
<tr>
<td>· Time</td>
<td>· Successful collaborations</td>
</tr>
<tr>
<td>· Resources (equipment) [in the classrooms]</td>
<td>· Creating trust and mutually respectful Teacher–Fellow partnerships</td>
</tr>
<tr>
<td>· Student skills and background knowledge</td>
<td>· Technology in classrooms (having it available)</td>
</tr>
<tr>
<td>· Standardized testing needs and emphasis [in the K–12 classrooms and how it might affect available options for Fellows’ activities in classrooms – varies from place to place]</td>
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<tr>
<td>· Teacher—Fellow selection and matching criteria (or lack thereof)</td>
<td>· Clarify Fellow’s role in the classroom (you’re scientists, not teachers)</td>
</tr>
<tr>
<td>· Unclear expectations (communicate your expectations: teachers need to be voluntary; otherwise there are misguided expectations)</td>
<td>· Not leaving Fellows alone in the classroom (not a strategy, just a rule [with potential legal implications if not followed and something happens!])</td>
</tr>
<tr>
<td>· Unpredictability in the classroom (TB tests and fingerprinting for Fellows, bomb scare in school)</td>
<td>· Constant communication (with all participants)</td>
</tr>
<tr>
<td>· Development of clear expectations</td>
<td>· Having a graduate student with previous teaching experience inform the project</td>
</tr>
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<td>· Poor communication and flow of information across organization</td>
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<tr>
<td>· “This is the first job (Fellow) I’ve had where I got in trouble for working too much” (i.e. need to balance Fellowship time and research time – a goal of graduate school is to graduate)</td>
<td>· Finding the best method of communication (meetings, team-building exercises)</td>
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<tr>
<td>· Not replacing the project manager who moved on after 2.5 years</td>
<td>· Fellow video to students (re: research work)</td>
</tr>
<tr>
<td>· Team building for equal partners with the grad student as “science expert” and the teacher as “science teaching expert”</td>
<td>· Intensive training institute with workshops through school year</td>
</tr>
<tr>
<td>· Pedagogy training that leads to products (curricular materials, teaching philosophy, publication, professional CV, etc.)</td>
<td>· Create lasting infrastructure and artifacts (e.g. effective web site, green houses, native plant gardens, curriculum material, local field guide)</td>
</tr>
<tr>
<td>· Paying close attention to our assessment feedback, the project has an expert and we have to learn from our data and adjust where necessary</td>
<td>· [not clear if this was referring to Fellows, teachers or both]</td>
</tr>
</tbody>
</table>
APPENDIX 6.1
EXAMPLES OF INTEGRATING RESEARCH IN THE CLASSROOM

INSPIRE GK–12, MISSISSIPPI STATE UNIVERSITY
Technology
A Fellow studying mechanical engineering and computer projecting created a semester-long project for a robotics course for 11th- to 12th-grade students at a math and science academy. Students began by learning basic projecting of Lego® Mindstorms® through guided activities. They were then assigned to small student teams and challenged to develop a computer project to create a functioning robot. The culminating task was a competition among the teams at a Robot Olympics. The Robot Olympics had a variety of competition tasks, including putting a ball in a designated cup, recognizing colors, and dancing to music, to name a few. Students were excited and engaged throughout the entire process.

A Fellow in a middle school science classroom used technology to teach a lesson on microscopes and “what cannot be seen with just the human eye.” He demonstrated the use of a benchtop scanning electron microscope to observe objects selected by the students and led a discussion of the features of the objects that were surprising to the students. The Fellow connected this activity to his own research on soil microorganisms, which can be seen only through microscopes.

A Fellow who studies the impacts of meteorology on agriculture conducted a lab in which middle school science students used handheld weather meters to collect weather data and predict weather patterns for the next day. Students collected data from various locations around the grounds of the school to compare differences in temperature, humidity, wind speed, and barometric pressure.

Hands-on activities
A Fellow who studies industrial engineering in the field of ergonomics of working environments and the human interface with equipment created an activity for a high school geometry class which allowed students to design a chair that could bear the most weight on the basis of their knowledge of which geometric shapes provide the most support. Students hypothesized which shapes would be the best form of support to use in their chair design and then used popsicle sticks to build the chair and test their hypotheses.

A Fellow who studies inorganic chemistry and metal reactivity showed several samples of metals in solution to eighth-grade science students who were studying metals in the periodic table. The students conducted a lab that involved flame testing a variety of known metals and observing the color produced in the flame. The students were then given unknown samples to determine, on the basis of their earlier observations, the type of metal in the solution and its location in the periodic table.

Demos
A Fellow who studies hydrogeology used toilet paper as a time line to demonstrate the expanse of geologic time to eighth-grade students. The students were led to the hallway by the Fellow, and the toilet paper was rolled out into segments while the Fellow described each geologic period, with each piece of toilet paper representing a grouping of years. By the end of the lesson, the students had walked the entire length of the hallway and toured the geologic timescale.

A Fellow who studies inorganic chemistry invited the local fire station to give high school chemistry students a lesson in fire safety as part of the laboratory safety unit. In the lesson, a firefighter demonstrated how to use a fire extinguisher, before allowing students to practice on a controlled fire on the school grounds. The lesson was followed by safety demonstrations conducted by the Fellow regarding the dangers of acid. The Fellow projected a cow’s eyeball onto a large screen in the classroom and inundated the eyeball with acid. The students saw a reaction quickly take place. The demonstration illustrated how fast acid can cause damage and brought home the point to the students that they need to wear safety glasses in the laboratory.

Didactic
A Fellow who studies invasive species of Australian pine and their acidic impacts on the soil introduced seventh-grade science students to the practice and importance of making observations in field research along with keeping copious notes on their observations and findings in a lab notebook. The
Fellow provided images of her field research in a PowerPoint presentation and then had the students share what they noticed about the surrounding environment of the invasive species as shown in the images. The Fellow also provided her field notebook for the students to see examples of the type of observations and data collection she made. The Fellow then related this lecture to the students' upcoming lab experiences.

STATE UNIVERSITY OF NEW YORK COLLEGE OF ENVIRONMENTAL SCIENCE AND FORESTRY
Games
A Fellow who studies nutrient cycles in grasslands introduced her environmental science students to the topic of the nitrogen cycle by developing a game in which the students work together to act out the steps of the cycle in the classroom. The “legume” and “symbiotic rhizobia” students linked arms and worked together frantically to cut apart the paper nitrogen (N₂) molecules. Then they passed the nitrogen atoms (N) on to the “soil,” who passed it on to the “plants,” and so on. This simple game got students excited and engaged in the topic. Building on that experience, the class then worked together to create a flow diagram of the nitrogen cycle. Finally, the Fellow gave a PowerPoint presentation that linked the nitrogen cycle to current global events related to agriculture, fossil fuels, and food security.

Didactic/Technology
Another Fellow who works on mosquito-borne diseases traveled to her field site in the tropics for a few weeks during the school year. While she was in the field, she emailed her high school students regular updates of her work, posted photos of her site online, and responded to student questions. When she returned, she talked about her experiences and shared photos and video, using a PowerPoint presentation.

EAST TENNESSEE STATE UNIVERSITY
Hands-on activities
A GK–12 Fellow incorporated her research on microbiology into a two-week unit on the basics of bacteria for a fourth-grade class. The unit was set up as a science experiment in which the students investigated the research question “Where in the classroom do the most bacteria grow?” In the first week, the Fellow facilitated a discussion that led the students to develop their own hypotheses about the location at which they thought the most bacteria would be found. Students then tested their hypotheses by swapping locations with one another and growing the bacteria in a petri dish. In the second week, the students gathered data by sketching the patterns of bacterial growth they observed under a microscope. Then they analyzed their data by ranking the bacterial growth between locations. On the basis of their analyses, they were able to make conclusions about their hypothesis and answer the research question.

OPIHI (OUR PROJECT IN HAWAII’S INTERTIDAL), UNIVERSITY OF HAWAII MANOA
Technology
Fellows developed inquiry-based projects and lessons to teach middle and high school students research skills. Students learned how to gather data on the various species of invertebrates (see photo below) found in Hawaii’s rocky intertidal, data that can inform scientists about environmental changes. The data were entered into an online database used by other scientific researchers and the public. Students were then involved in various activities, such as science fair projects and creating brochures and posters, to communicate and share their findings.
APPENDIX 6.2

LESSON PLAN: ENGINEERING COST ANALYSIS BY DESIGN OF A WATER FILTER

GRADE LEVEL
It is targeted for grade 6.

SUBJECT AREA
Math, Science

KEYWORDS
Activated carbon, cost analysis, design, engineering, filter, food coloring, greywater, particulates.

LEARNING OBJECTIVES
This activity serves two purposes. The first is to reinforce topics that the students will be familiar with such as addition, multiplication and sales tax calculation. The second objective is to introduce the engineering design concept of proper material selection and the impact that material costs have on a design. The students will build a water filter using various materials with an assigned cost. Colored water will be run through the filter with the goal of filtering the color from the water. Student designs will be evaluated by two criteria. The first will be to visually inspect the filtered water and determine if the color was removed. The second will be to compare the cost of the water filter. The best class design is determined by comparing filtration capability and lowest design cost.

ENGINEERING/SCIENCE CONNECTION
One of the steps utilized in treating greywater is to filter it to remove larger particles. Various degrees of filtration of water exist. The level of filtration depends on the intended use of the end product. Removing fine particles through the filtration process is required if the end goal is obtain water for consumption. Engineers involved in water purification/treatment are involved in engineering processes or machinery that can perform the proper filtration. One of the constraints an engineer encounters in the design process is the constraint of cost. As an engineer, he/she is tasked with designing a process or product within a certain cost. It is possible to develop a product that accomplishes the same task but may vary in cost. In this activity students learn how to design and build a basic water filter. The students will have the freedom to design their filter as they choose and will calculate the cost to build their filter.

TIME REQUIRED
The activity can be completed in 1hr 50 minutes. This includes an introduction to the activity (10 mins.), instructions (10 mins.), performing the activity and completion of the “Water Filter” worksheet (90 mins.).

GROUP SIZE
Group size is between 1 and 3 students. Material availability and class size will usually dictate group size.

EXPENDABLE COST PER GROUP
Cost for a group size of 20 to 25 students is approximately $20.

EDUCATION STANDARDS
Sixth Grade Standard 6.b. (Sales tax calculation)

MATERIALS LIST

Materials List:
1. Activated carbon: A 16oz container would be needed for a class of approximately 20–25 students. This item can be purchased at www.amazon.com for approximately $7.00, keyword: Black Diamond Activated Carbon. This item can be reused.
2. Cotton rounds, 240 count. This item can be purchased at www.walgreens.com for approximately $4.50, keyword: Cotton round
3. Cotton balls, 100 count. This item can be purchased at www.walgreens.com for approximately $1.50, keyword: Cotton balls
4. Clear Plastic Cups, 50 count. This item can be purchased at www.partycity.com for approximately $6.00, keyword: Clear plastic cup, 10oz, 50ct. This item can be reused.
5. Water bottles. This item should not be purchased but should be collected prior to the activity and recycled or reused.

SOURCE: CALIFORNIA STATE LOS ANGELES, IMPACT LA
6. Water Filter Worksheet. One worksheet per student would be required.

PREREQUISITE KNOWLEDGE
To be successful, the student should have knowledge of basic arithmetic and sales tax calculation.

ACTIVITY BACKGROUND AND CONCEPTS FOR TEACHERS
This activity will introduce the basic operation of a water filter. It will also expose the students to consider the impact that their design decisions have on the cost of their design. Students will learn that particles can interfere with bacteria inactivation. From the introduction of the activity, discussed later, the students should know that the UV light does not kill the bacteria but instead prevents them from reproducing.

The teacher should have a basic understanding of water filtration and its role in the water treatment process. A filter, as shown in Figure 1, functions by preventing predefined particle sizes from passing through the filter material. A filter is selected to remove particle sizes up to a specified size.

Activated carbon (Figure 2) is known by other names such as activated charcoal or activated coal. Activated carbon is used in various forms some of which include powder, granulated, granular and extruded. For this activity we use the granulated form. Activated carbon is used in water treatment because each granular piece of carbon is very porous and has a large surface area for removing water impurities. Activated carbon is used in commercial water filters to purify water for drinking.

The teacher should have a basic understanding of what ultraviolet light is. The basic concepts are that ultraviolet light is part of the electromagnetic spectrum that has a wavelength between 100nm and 400nm. The unit of measure for the different wavelengths in the spectrum are measured in nanometers, nm. A nanometer is 10^-9 meters, which is 1 billionth of a meter. UV light can’t be seen by the human eye. In comparison, the portion that can be seen by the naked eye is between 380nm and 750nm. Figure 3 shows the electromagnetic spectrum. The different types of light that make up the electromagnetic spectrum are measured in wavelengths.

INTRODUCTION/MOTIVATION
The following is a guide as to how the lesson can be introduced to the class.

Research is being conducted to study the effects that ultraviolet light produced from light emitting diodes has on greywater pathogens. The idea is to be able to treat greywater so we are able to reuse it. Before we continue let’s define a few words. Ultraviolet light is a type of radiation. We experience UV radiation every time we step into the sun. Has anyone ever been sunburn? If you have, the sunburn was caused by ultraviolet lights. Has anyone seen businesses where you can get a tan? They use UV lamps to get people tanned. UV light is nice for tans, but it can also be bad if we get too much. It can cause negative effects like cancer. This is why it’s important to wear sunblock.

Research into UV light was conducted because it was identified as causing harmful bacteria and viruses to stop reproducing. This is why UV light is used in water treatment. Light emitting diodes or LEDs are small sources of light that can artificially create UV light. Until recently, lamps were used to create artificial UV light but LEDs use less energy and last approximately 10 times longer. Greywater is water that comes from our homes. It’s defined as any water that comes from our sinks, bathtubs, washing machines or similar sources except from the toilet. Water that comes from our toilets is called black-water. Researchers are investigating how they can treat this greywater that we produce daily in our homes so we can reuse it. If the bacteria and viruses that are found in greywater were removed using UV light, it would be safer for people to reuse. Has anyone seen a commercial about water droughts? This is a serious issue. As the cities and our population grow, we use more water. If we don’t do something about it we can run out and that would be very bad. What is one way we can do our part to help? (Answers: Using less water, recycling) What if we could reuse all the water we use for showering, washing dishes and washing our clothes? Do you think that would help us conserve
Wouldn’t it be great to use this water again and not have to use clean drinkable water instead? What are some uses you think we can reuse this water, that doesn’t include drinking it? (Answers: Washing our cars, watering the lawn, flushing our toilets). A goal researchers have is to determine if the greywater can be treated to ensure it is safe for us to reuse.

In this activity we will design our own filtration systems. The filtration systems are important because they remove large particles from the greywater before being treated further. You will get into groups of two and be given certain materials. Each material has an assigned cost to it. You will design your filtration system and determine the total cost to build and operate it. This is a real world situation. Products that are designed have to be designed with cost in mind.

**VOCABULARY/DEFINITION**

1. Activated Carbon: This is a form of carbon that is defined by very fine pores. It is used to absorb gases and solutes. It’s main uses are in purification, deodorization and decolorization.
2. Filtration media (Filter): A substance, usually porous, through which liquid is passed to remove suspended particles or impurities.
3. Ultraviolet (UV) light/ray: Ultraviolet light is part of the electromagnetic spectrum that has a wavelength between 10nm and 400nm. It is not visible by the human eye.
4. Greywater: Water from residential sources such as sinks, bathtubs, washing machines but excludes sources such as toilets.
5. Black water: Water from sources such as toilets or other sources containing human/animal waste.
6. Bacteria: single celled organisms that are typically spherical, rod-shaped or spiral shaped. Bacteria are part of the process in fermentation, infectious diseases, nitrogen fixation and putrefaction.
7. Virus: A microscopic agent that is typically infectious. It reproduces itself within the cells of other living hosts like bacteria, plants and animals.
8. Disinfection: To get rid of microorganisms that are potentially harmful.
9. Particle: A piece, fragment or minute portion. It is considered a tiny or small portion. Example: A particle of dust.

*(NOTE: Definitions paraphrased from Dictionary.com)*

**DESIGNING A WATER FILTER**

**Procedure**

**Step 1:** Introduce the activity. Use the guide of how to introduce the activity from the “Introduction/Motivation” Section. The students should know they will be designing and building a water filter. They should know that they will be allowed to select the materials to use in the filter but that each material has a fixed cost.

**Step 2:** The instructor should prepare the colored water ahead of time. Each group should receive a 16 ounce bottle of colored water. Food coloring should be used. Green food color is recommended but other colors can be substituted if needed. The teacher should also prepare the water bottles needed for the students’ filters prior to commencing the project. The bottom of a 16 oz water bottle should be cut-off. For a class of 36 students 18 water bottles should be used. Group the students in pairs. Instruct the students that they should plan and design their design prior to building the filter.
**Step 3:** Conducting the Activity
Pass out the worksheet, “Designing a Water Filter”. Read the worksheet to the students. The worksheet explains the procedure the students must take to complete the activity. Inform the students that as they purchase the materials they must record the quantity they purchase and compute the subtotals.
(Note: Students should not be allowed to use only the activated carbon.)
(Note: This activity involves the use of water. Make sure to have napkins available for possible spills that may occur.)

**Step 4:** When the student(s) complete the design and build their filter, allow them to cycle the colored water through their filter. Make sure they place their filter inside the clear plastic cup as shown in Figure 4. They should see a reduction in the color of the water. If they choose to cycle the water again have the student use a second clear cup and place it under the water filter and use the water in the cup and filter it. The students can filter the water as many times as they want. Let them know that each time the water is cycled, it will cost them the predefined amount. After the students are satisfied with the outcome of the water, the total cost should be computed.

**Step 5:** The teacher should compare how each group’s filter and costs compare to one another. If desired, a top overall design can be selected.

**SUPPLEMENTARY MATERIALS**
Water Filter Worksheet

**ASSESSMENT**
The following pre and post questions should be asked for assessment purposes:

**Pre-Activity Assessment:**
1. Why is it important to have drinking water without any particles of dirt or other particles in it? Answer: The particles may cause us harm if we drink them and/or make us sick.
2. Is it important to consider cost when designing a product? Would you buy a bottle of water if it cost $10? Answers: Probably not. We would drink tap water if bottled water were that expensive.
3. Is selecting the proper materials to design a product important or is it more important to design a product no matter the cost? Answer: Allow students to give their answers. Ask this question again after the activity.

**Post-Activity Assessment:**
1. What material was most effective in removing the color from the water? Answer: There is no right and wrong answer as this depends on the student’s design.
2. What design changes would you make to improve your design? Would you use more materials to improve the filtration performance or less material to reduce costs? Answer: There is no right and wrong answer to this question.

**REFERENCES**
1. Malcolm Pirnie, Inc.
2. Carollo Engineers, P.C.
3. The Cadmus Group, Inc.
4. Dr. Karl G. Linden and Dr James P. Malley, Jr.

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Water Filter Worksheet

Objective
A preliminary filtration system will be important in a water treatment system. Preliminary filtration removes large particles such as dirt or gravel from the water. This is important in a water treatment system that uses ultraviolet light for secondary treatment since any large particles in the water will prevent bacteria from being treated.

Your goal is to perform a preliminary filtration on the provided greywater. Greywater is a term for residential water that comes from any source other than toilet water. Examples would be shower water, dishwater or laundry water. You will design and build a portable filtration system. The system you design will be used to filter and clean the water as much as possible. You may cycle the water through your system as many times as needed to obtain your desired filtration. The colored guide, Figure 1, can be used to determine the level of filtration achieved.

It would be nice to design and develop the filtration system without worrying about costs but since we live in the real world we need to take costs into consideration. The total cost of filtering the greywater will depend on the materials you use to build your filtration system and the number cycles used. Use the following table to document the materials used and the number of cycles used to filter the greywater and calculate the total cost of filtration.

### Materials:
- Water Bottles: $5.00/each
- Cotton Balls: $.50/each
- Cotton Rounds: $2.00/each
- Activated Carbon: $10.00/spoonful
- Cups: $1.00/each
- Cost per cycle: $15.00/cycle

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<th>Costs</th>
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<td>Activated Carbon</td>
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<td>Cups</td>
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<td>9.75% Tax</td>
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<td><strong>Total Cost + Tax</strong></td>
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(Note: Can’t buy only activated carbon.)

Figure 1: Color Guide

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APPENDIX 6.3
LESSON PLAN: SIEGE THAT CASTLE

<table>
<thead>
<tr>
<th>Lesson Title</th>
<th>Projectile lab “Siege that castle!”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of Lesson</td>
<td>1 day</td>
</tr>
<tr>
<td>Created By</td>
<td>Henry Stauffenberg IV, William Funderburk</td>
</tr>
<tr>
<td>Subject</td>
<td>Physics</td>
</tr>
<tr>
<td>Grade Level</td>
<td>9–12 (Physics)</td>
</tr>
<tr>
<td>State Standards</td>
<td>Physics:1a,b,c,d,e,f;2a,b,c</td>
</tr>
<tr>
<td>Depth of Knowledge (DOK) Level</td>
<td>Physics: 3</td>
</tr>
<tr>
<td>DOK Application</td>
<td>Create, inquire, hypothesize, organize, collect, interpret, investigate, connect, explain, prove, draw conclusions, graph, predict, regress</td>
</tr>
<tr>
<td>National Standards Graduate</td>
<td>9–12 A: Inquiry; B: Physical Science;</td>
</tr>
<tr>
<td>E: Science and Technology</td>
<td>Working with Excel for statistical analysis and presentation of data collected and drawn from experimentation. Creation of range table and improving it, using applied knowledge of basic calculus and physics. Importance of experimental design and development of critical Excel skill set.</td>
</tr>
</tbody>
</table>

Student Learning Goal:
The purpose of this lesson is to re-create a medieval range table and learn the importance of experimental design and Excel application and analysis. Students will utilize the range table (graphing through Excel) to regress a quadratic equation that describes the accuracy of a projectile; in other words, students will use the power of math to knock down a castle wall. The goal is to get students thinking about nonlinear multidirectional motion and to expand upon what they have learned about vectors, velocity, and acceleration due to gravity.

Mississippi State Standards
Physics: 1: (a) Use current technologies, such as CD-ROM, DVD, the Internet, and online data searches, to explore current research related to a specific topic; (b) clarify research questions and design laboratory investigations; (c) demonstrate the use of scientific inquiry and methods to formulate, conduct, and evaluate laboratory investigations; (d) organize data to construct graphs, draw conclusions, and make inferences; (e) evaluate procedures, data, and conclusions to critique the scientific validity of research; (f) use logic and evidence to formulate and revise scientific explanations and models; 2: (a) Use inquiry to investigate and develop an understanding of the kinematics and dynamics of physical bodies; (b) analyze, describe, and solve problems by creating and utilizing graphs of one-dimensional motion; (c) Analyze real-world applications to draw conclusions about Newton’s three laws of motion.

National Science Education Standards of Content 9–12
A: Inquiry: Identify questions and concepts that guide scientific investigations:

- Students should formulate a testable hypothesis and demonstrate the logical connections between the scientific concepts guiding the hypothesis and the design of an experiment. They should demonstrate appropriate procedures, a knowledge base, and a conceptual understanding of scientific investigations.

B: Physical Science—motion and forces:

- Objects change their motion only when a net force is applied. Laws of motion are used to calculate precisely the effects of forces on the motion of objects. The magnitude of the change in motion can be calculated from the relationship F = ma, which is independent of the nature of the force. Whenever one object exerts a force on another, a force equal in magnitude and opposite in direction is exerted on the first object.

- Gravitation is a universal force that each mass exerts on any other mass. The strength of the gravitational attractive force between two masses is inversely proportional to the square of the distance between them.

E: Science and Technology—understanding about science and technology:

- Scientists in different disciplines ask different questions, use different methods of investigation, and accept different types of evidence to support their explanations. Many scientific investigations require the contributions of individuals from different
disciplines, including engineering. New disciplines of science, such as geophysics and biochemistry, often emerge at the interface of two older disciplines.

Materials Needed (supplies, handouts, resources): Pasco spring-operated projectile launcher, plastic or wooden balls of standard size and mass, grid paper, carbon paper, meterstick, computer and Excel program, cup or equivalent object to represent castle tower or wall.

Lesson Performance Task Assessment:
• Demonstrate ability to use Pasco equipment and create range tables
• Demonstrate ability to design and work in a lab, using available materials
• Demonstrate ability to create graphs and regression equations in Excel
• Show work, using carbon and graph paper and good note taking
• Demonstrate ability to use equations to hit an object placed at a set measured distance
• Complete a lab write-up

Relevance of Lesson to Performance Task and Students:
• To practice experimental design, using specialized Pasco equipment
• To understand the importance of experimental design by completing a range table, a graph with Excel, and a regression of a quadratic equation to meet the objective of knocking down the opponent’s wall with one calculated shot
• To gain insight into medieval times (learn a bit of history) and into the importance of projectile motion and the rise of physics
• To apply what the students have learned, such as the concept and equations of projectile motion, and to connect, compare, and contrast what they have learned with previously learned linear motion (free fall of objects affected by gravity)

Capture Interest:
Sitting at each class table is a barbarian horde (or Celtic/Germanic tribe) that recently “appropriated” a Roman catapult. Your reigning warlord demands that you, the engineers, investigate and document the capabilities of this new siege weapon of war. Unfortunately, the last pillaging and burning destroyed the range table created by the Romans. You will have to re-create this table through testing and documenting results. Being the clever engineers that you are, you realize the power of math and figure that you can improve upon the table and one up the Romans by graphing it and regressing an equation for calculating the precise placement of a projectile. If you are successful, you will have revolutionized siege warfare, making seizing and pillaging territories far more efficient.

After the class creates a graph: Your warlord has grown tired of your restless barbarian neighbors and wishes to test your siege weapon on them in order to destroy the competition. Your neighbors wish to do the same to you, so every shot counts, as this looks like war. One shot, one kill—the last barbarian encampment standing wins. It’s time to put your range table and equation to the test: The global conquest of the physics classroom begins!

Historical Note:
Castles and siege weaponry were at their height during the medieval era shortly after the collapse of the Roman empire; however, neither the Greeks nor the Romans utilized or pioneered siege weapons such as the ballista or the grapeshot catapult. During the 1300s, trebuchets and the use of range tables remained the primary method of siege warfare, and they did so for hundreds of years afterward, until calculus was applied to physics to replace the range table. The application of calculus to physics during World War II was revolutionary, enabling the calculation of shell trajectories aimed at battleships and precise artillery bombardment of enemy targets, thereby contributing to the Allies’ victory during World War II.

Guided Practice:
Show how to use a projectile launcher safely, and demonstrate how to load the launcher, set the spring, and adjust the angle. Make it clear that the student is to click only into the first spring setting. Then show how to measure the horizontal distance up to the graphing paper (in centimeters) with a carbon sheet laid over the top. Launch a ball and have it hit carbon paper, leaving a mark on the graph paper. Make it clear that the student is to lift the carbon paper and label each shot. Each table will fire five shots at a wide range of angles, to avoid clustering of data. Each shot is done in triplicate (fired at the same angle and recorded
three times in a row). Explain the importance of triplicate recording by connecting graduate research with averaging and the accuracy of data. Make it clear that the only measurements the students will be recording on the table (after the shot is fired) is the horizontal distance the projectile travels and the angle of attack. Students should choose how to organize their tables; however, giving a sample table for triplicate work is recommended, as students may be working with Excel for the first time. After the tables are created, walk through a class demonstration creating a graph with Excel and regressing a quadratic equation from the data. Explain briefly how the formula can be used to calculate the angle or horizontal distance when one variable is known. For the war scenario, explain that each team will place its cup (castle) at any linear distance from the catapult. The team operating the catapult will measure the distance to the castle and insert the measured value into its equation. If the equation is good, the projectile should hit the cup on the first shot; however, it most likely will take a few shots because of other variables at play.

Either before or after generation of the range table, explain to the students that they will also calculate the muzzle velocity (initial horizontal velocity) of their projectile launcher. They must set it to zero degrees, record the horizontal distance the projectile travels, and record the vertical distance from the floor to the middle of the barrel. Give them the two projectile equations to calculate the travel time and the initial velocity in the horizontal direction. Explain that they will manipulate the first equation so as to substitute time into the second equation. That way, they won’t have to know the time, and they can insert their vertical and horizontal measured distances into the appropriate equation to calculate the initial muzzle velocity. This exercise will be homework, because the creation of the range table is more important, especially if they are to compete in the war scenario described earlier.

**Independent Practice:**
Calculation of the muzzle velocity and other components of projectile motion if needed, such as a change in vertical direction or vertical initial velocity.

**Enrichment:**
Ask for students’ calculated vertical projectile components, using their horizontal data. Have students further explain and connect applied concepts to the lab they have just completed. Have them use equations to hit more difficult targets.

**Check(s) for Understanding:**
- Successful completion of range table and quadratic equation
- Ability to use equation to hit target castle
- Correct calculation of muzzle velocity
- Ability to explain in a report what they did and why it was important and ability to connect together the material they learned in previous lectures about projectile motion, free fall, Newton’s laws of motions, and the effect of gravity

**Closure:**
Mention the historical note stated previously, or end with a class discussion on Newton’s laws of motion and other material that the class will be moving into beyond projectile motion.

**Possible Alternative Subject Integrations:**
Calculus: Regression models, line equations, and formulas using algebraic calculations

**Teacher Notes:**
Pick an open room, place launchers in areas that will avoid potential damage to computers and other breakables, and do not use ammunition that has a lot of bounce to it. Keep an eye on the students, because they can hurt themselves if safety procedures are not followed.
Student Learning Goal:
Students will observe how water droplets interact with various surfaces and will learn the concept of surface wettability. They will learn the difference the smoothness of a surface makes when water droplets come in contact with the surface. For example, smoother surfaces or superhydrophobic surfaces tend to have higher contact angles and are considered less wettable. Protractors will be used to measure the contact angle of a water droplet on a variety of surfaces. Students will use the Proscope to see better and will make conclusions about the smoothness of the surface. Students will use rulers to measure the spread of the droplet in contact with the surface and the height of the droplet as it sits on the surface.

Materials Needed (supplies, handouts, resources):
Water, surface samples, droplet dispenser, 2–3 Proscopes, 2–3 computers and projectors, protractors, rulers

Lesson Performance Task/Assessment:  
After seeing the demonstration of water droplets striking various surfaces and after observing the difference between superhydrophobic, hydrophobic, and hydrophilic surfaces, students will learn the definitions of contact angle, spread, and height. Students will work in small groups and will use the Proscope (with supervision) to observe water on two or three different surfaces. Using a ruler and protractor, they will measure the contact angle, spread, and height to scale. By holding a rule up to the picture on the screen, they will realize that the picture is not to scale. In order to measure it to scale, the measuring device must be observed next to the droplet and viewed within the Proscope.

Lesson Relevance to Performance Task and Students:
Students will understand that not all surfaces are the same. This understanding will help them realize that not all surfaces can be used on aircraft wings if ice is to be prevented. They will also learn to use measuring devices in a real-world research setting.

Anticipatory Set; Capture Interest:
Without offering any explanation, the instructor will demonstrate water striking three different surfaces. Students may expect to see the same results on each surface, but will observe that water does not interact with each surface in the same way. This demonstration should pique the students’ curiosity, and a discussion will be prompted with the following questions:
• Which surface repels water the most?
  – Explain wettability
  – Is the surface that repels water more or less wettable?
– Which surface should be used if you do not want ice to build up on your aircraft?

The instructor will use the Proscope to show a close-up of a water droplet on one of the surfaces.

• What kind of measurements can we make to describe the droplet on this surface such that we can use these measurements to compare the droplets with droplets on other surfaces? (contact angle, spread, and height)

Guided Practice:
The instructor will define contact angle, spread, and height. Students will work in three groups and rotate among three stations. At each station will be a Proscope set up to observe a droplet on a superhydrophobic, hydrophobic, and hydrophilic surface. The instructor will guide the students how to measure the three variables, and the students will collect and record the data at each station on their own. The instructor will assist as needed. Once the students have collected the data, the instructor will ask them what observations they made about each station and how their data compared. The instructor will conclude with the definitions of superhydrophobic, hydrophobic, and hydrophilic surfaces and ask students to try to classify the sample at each station. Students will apply their understanding of each surface to a real-world application—for example,

• Why would an engineer want to use a superhydrophobic surface versus a hydrophilic surface?

Closure:
The instructor will conclude with the definitions of superhydrophobic, hydrophobic, and hydrophilic surfaces and will ask students to try to classify the sample at each station. Students will apply their understanding of each surface to a real-world application—for example,

Possible Alternative Subject Integrations:
Use physics to explain effects of densities, viscosity, and velocity.

Teacher Notes:
Show students pictures through a PowerPoint presentation. Make sure that there is an instructor at each station to monitor the usage of Proscopes.

Independent Practice:
Students will work independently at each station to measure and collect their data on each droplet. The teacher will walk around and assist as needed. Students will be asked to discuss their data with each other.

Remediation and Enrichment:
If the Proscopes aren’t working in the classroom or the image isn’t of good quality, the instructor will have handouts of a picture of a droplet on each surface available for students to use to measure. Individual IEPs will be supported. For enrichment, or if there is extra time, the students can use surfaces in the room on which to observe and collect data. These surfaces could include desktops of various roughness, chairs, textbooks, glass, etc. They can compare data taken from these surfaces with the data collected at the stations and can then make conclusions about the various surfaces.

Check(s) for Understanding:
Students will be asked to classify the surfaces as superhydrophobic, hydrophobic, and hydrophilic. They will be asked for examples of where and why an engineer might want to use a hydrophilic surface rather than a hydrophobic surface, and vice versa.
APPENDIX 9.1
SAMPLES OF GK–12 EVALUATION INSTRUMENTS

GK–12 FELLOWS PROGRAM EVALUATION (FELLOW)

Name ________________________________ Date ________________
School ________________________________ Lead Teacher ________________________________

Please evaluate your experience in the GK–12 Fellows Program by rating your agreement with each of the statements listed below according to the scale provided.

Agreement Levels
1=Strongly Disagree...5=Strongly Agree

Overall GK–12 Program Evaluation

Integration:
I was perceived as a role model by students and faculty in my school. 1 2 3 4 5
Students viewed me as a teacher more than a scientist or mathematician. 1 2 3 4 5
I served as a school-wide resource. 1 2 3 4 5
Many activities included math and science principles regardless of the class in which they were presented. 1 2 3 4 5
Inquiry learning was increased in my classroom due to my activities. 1 2 3 4 5
PEER modules were presented in my classroom. 1 2 3 4 5
I increased and improved the use of technology in my classroom. 1 2 3 4 5

Team Contact:
I provided a useful link between my lead teacher and university faculty. 1 2 3 4 5
University faculty conducted a presentation in my classroom. 1 2 3 4 5
I involved my faculty mentor when questions arose regarding their area of expertise. 1 2 3 4 5
My students benefited from my contact with university faculty. 1 2 3 4 5
PEER Web resources, such as virtual scientist visits and interviews, were presented in my classroom. 1 2 3 4 5
I involved other RM/RSs in my classroom activities. 1 2 3 4 5
My students were influenced by TAMU employees other than myself. 1 2 3 4 5

Interaction Results:
I improved my lead teacher’s content knowledge. 1 2 3 4 5
I have a better understanding of education principles because of working with my lead teacher. 1 2 3 4 5
My activities improved students’ learning of state standards. 1 2 3 4 5
I used my entire budget for classroom supplies. 1 2 3 4 5
I provided supplies that my lead teacher will be able to use next year. 1 2 3 4 5

SOURCE: GK–12 FELLOWS INTEGRATE SCIENCE/MATH IN RURAL MIDDLE SCHOOLS, TEXAS A&M UNIVERSITY.
**Agreement Levels**
1=Strongly Disagree...5=Strongly Agree

<table>
<thead>
<tr>
<th>Program Organization:</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>I spent at least 8 hours working directly with students each week.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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<tr>
<td>At least 1 hour was spent planning for upcoming events with the lead teacher weekly.</td>
<td>1</td>
<td>2</td>
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<td>5</td>
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<tr>
<td>Distance Learning Community requests involved my area of expertise.</td>
<td>1</td>
<td>2</td>
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<td>4</td>
<td>5</td>
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<tr>
<td>Time spent with Distance Learning Requests is reasonable and worthwhile.</td>
<td>1</td>
<td>2</td>
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<tr>
<td>It is important for professionals in my field to contribute to K–12 math and science education.</td>
<td>1</td>
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<tr>
<td>Spending 10 hours per week in a middle school classroom interfered with my other obligations as a graduate student.</td>
<td>1</td>
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<tr>
<td>The GK–12 program has influenced how I will contribute to public education in the future.</td>
<td>1</td>
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<tr>
<td>I have learned about needs and difficulties of public education through my involvement in this program.</td>
<td>1</td>
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<tr>
<td>I am more organized due to my involvement in this program.</td>
<td>1</td>
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</tr>
<tr>
<td>I was able to participate in the GK–12 program and still perform scholarly duties expected of a graduate student.</td>
<td>1</td>
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<tr>
<td>I have gained communication skills through the GK–12 program.</td>
<td>1</td>
<td>2</td>
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<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
SETAKIST* TEACHER EVALUATION

Please indicate the degree to which you agree or disagree with each of the following statements by circling the appropriate number to the right of each statement.

* Self Efficacy Teaching and Knowledge Instrument for Science Teachers

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Uncertain</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. When teaching science, I usually welcome student questions.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>2. I feel I have the necessary skills to teach science.</td>
<td>1</td>
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<tr>
<td>3. I am typically able to answer students’ science questions.</td>
<td>1</td>
<td>2</td>
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<tr>
<td>4. Given a choice, I would encourage the principal to evaluate my science teaching.</td>
<td>1</td>
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<tr>
<td>5. I feel comfortable improvising during science lab experiments.</td>
<td>1</td>
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<td>6. I feel that I am able to teach science as well as I teach most other subjects.</td>
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<td>7. After I have taught a science concept once, I feel confident teaching it again.</td>
<td>1</td>
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<td>8. I find science a relatively easy topic to teach.</td>
<td>1</td>
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<td>9. I know the steps necessary to teach science concepts effectively.</td>
<td>1</td>
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<td>10. I can explain to students why science experiments work.</td>
<td>1</td>
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<td>11. I am continually finding better ways to teach science.</td>
<td>1</td>
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<td>12. I generally teach science effectively.</td>
<td>1</td>
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<tr>
<td>13. I understand science concepts well enough to teach science effectively.</td>
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<td>14. I know how to make students interested in science.</td>
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<td>15. I feel comfortable when teaching science content that I have not taught before.</td>
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<td>16. I feel I have a good understanding of the science concepts I teach.</td>
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<td>5</td>
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</tbody>
</table>

SOURCE: BAYLOR COLLEGE OF MEDICINE GK–12
**STUDENT INTEREST SURVEY: SCIENCE PRETEST**

School Name: _______________________________________________________________________________

Teacher’s Name: _____________________________________________________________________________

Resident Scientist’s Name: _____________________________________________________________________

Your Student Number: ___________________________ Grade: ________ Gender: **M** or **F** (please circle)

*The following statements relate to beliefs and interests in science. Check the box that most closely matches how you feel about each statement.*

<table>
<thead>
<tr>
<th>Beliefs about Science</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Uncertain</th>
<th>Agree</th>
<th>Strongly Agree</th>
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</thead>
<tbody>
<tr>
<td>1. I enjoy science class.</td>
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<td>2. I think I could be a good scientist.</td>
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<td>3. I like to find answers to questions by doing experiments.</td>
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<td>4. I get to do experiments in my science class.</td>
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<td>5. Being a scientist would be exciting.</td>
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<td>6. Science is difficult for me.</td>
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<td>7. I like to use the science book to learn science.</td>
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<td>8. Science is useful in everyday life.</td>
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<td>9. Studying hard in science is not cool.</td>
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<td>10. Scientists help make our lives better.</td>
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<td>11. Being a scientist would be boring.</td>
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<tr>
<td>12. I want to take more science classes.</td>
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</table>

<table>
<thead>
<tr>
<th>Interest in Science</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Uncertain</th>
<th>Agree</th>
<th>Strongly Agree</th>
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</thead>
<tbody>
<tr>
<td>13. I think science is important only at school.</td>
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<td>14. I like to use computers to learn about science.</td>
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<td>15. Science tests make me nervous.</td>
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<td>16. I like to use science equipment to study science.</td>
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<td>17. I usually don’t try my best in science class.</td>
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<td>18. The things we study in science are not useful to me in daily living.</td>
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</tr>
<tr>
<td>19. I like to work in a small group in science class.</td>
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</tr>
<tr>
<td>20. Science class activities are boring.</td>
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</tr>
<tr>
<td>21. Finishing high school is very important to me.</td>
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</tr>
<tr>
<td>22. I get better grades than most of my classmates in school.</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>23. I always give my best effort on my school homework.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24. I like being in school.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25. My family cares about the grades I get in school.</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26. I like science more than all other subjects in school.</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>27. My friends and I compete for the highest test scores in science class.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28. I will definitely go to college someday.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SOURCE: GK–12 FELLOWS INTEGRATE SCIENCE/MATH IN RURAL MIDDLE SCHOOLS, TEXAS A&M UNIVERSITY
29. List five words that describe a Scientist: ____________________________________________________

30. What are three things Scientists do when they are doing science? ______________________________
___________________________________________________________ ______________________________
___________________________________________________________ ______________________________

31. Do you think you could become a Scientist? Why? ____________________________________________
__________________________________________________________ ______________________________

APPENDIX 9.1
Please evaluate your experience in the GK–12 Fellows Program by rating your agreement for the Graduate Fellow section and the Overall GK–12 program section, using the scale provided.

### Graduate Fellow Program Evaluation

<table>
<thead>
<tr>
<th>Agreement</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>My graduate fellow was able to participate in the GK–12 program and still perform scholarly duties expected of a graduate student.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Spending 10 hours per week in a middle school classroom interfered with the other obligations of my graduate fellow.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>My graduate fellow often asked for help when questions arose in the classroom involving my area of expertise.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I am a good resource for middle school teachers through my graduate fellow.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>The activities presented at the semester retreat were a good use of time for my graduate fellow.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>My graduate fellow has gained communication skills through the GK–12 program.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>My graduate fellow is better organized due to involvement in this program.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>The amount of time and effort expected from faculty mentors of graduate fellows is realistic.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>The amount of time and effort expected from my graduate fellow is unrealistic.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

### Overall GK–12 Program Evaluation

<table>
<thead>
<tr>
<th>Agreement</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Southwest Regional NSF GK–12 Conference allowed me to see the worth of this program.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I have reviewed several requests for the Distance Learning Community.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I will continue to serve as a mentor for graduate fellows in the GK–12 program.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I will recommend that other graduate students apply for this fellowship.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Middle school students have benefited from my involvement in this program.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>It is unimportant for professionals in my field to contribute to K–12 math and science education.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I have learned about needs and difficulties of public education through my involvement in this program.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Distance Learning Community requests rarely involve my area of expertise.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Time spent with Distance Learning Community requests is reasonable and worthwhile.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>The amount of time and effort expected from faculty mentors of graduate fellows is realistic.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

**Sample Content Workshop Topical Areas**

- Unifying Ecological Themes
- Forming Partnerships with Scientists
- Developing School Ecology Outdoor Laboratories
- Tools and Techniques for Ecological Sampling
- Authentic Assessment for Science

**Fellow Training (Jan—May)**

- Teaching Science
- GK–12 Seminar

**SOURCE:** GK–12 FELLOWS INTEGRATE SCIENCE/MATH IN RURAL MIDDLE SCHOOLS, TEXAS A&M UNIVERSITY.
We would like to recognize the GK-12 community for their outstanding work and dedication to the program’s goals. We learned from their projects and are pleased to share their experiences and knowledge through these pages. This publication would not have been possible without the contributions of many people. Some provided case studies and pictures; others read and edited multiple manuscript drafts. Many others offered good ideas and specific material. We thank the members of the writing team (chapter authors in bold below) for answering our call to share the lessons learned from their experience with the GK-12 approach. We give a special thanks to the leaders of the writing teams, Carol Brewer, Vikram Kapila, and Donna Llewellyn, who oversaw the development and organization of the chapters.

Jessica Abel Feld
GK12 Project Coordinator
Project EXTREMES and ECSITE
University of Colorado
Boulder, CO

Richard Boone
Program Director
Division of Graduate Education
National Science Foundation
Arlington, VA

Laura Conner
Director of Outreach
College of Natural Science and Mathematics
University of Alaska
Fairbanks, AK

Paul J. Allan
Project Manager
Waters of the West GK-12
University of Idaho
Moscow, ID

Carol Brewer
Professor Emeritus
Biological Sciences
University of Montana
Missoula, MT

Tapas Das
Professor
Industrial and Management Systems Engineering
University of South Florida
Tampa, FL

Ailene Altman Mitchell
Principal
Middle School 88
Brooklyn, NY

Cynthia Brossman
Director of Learning Resource Network
Boston University
Boston, MA

S. Monroe Duboise
Associate Professor
Molecular Biology and Microbiology
University of Southern Maine
Portland, ME

Gordon Anderson
Dean
College of Arts and Sciences
East Tennessee State University
Johnson City, TN

Bruce Bukiet
Associate Professor
Mathematical Sciences
New Jersey Institute of Technology
Newark, NJ

Patrick Edwards
PhD Student
Environmental Science and Management Department
Portland State University
Portland, OR

Robert Chen
Professor
Environmental Earth and Ocean Sciences
University of Massachusetts
Boston, MA

Monica Elser
Education Manager
Global Institute of Sustainability
Arizona State University
Tempe, AZ

Adam Christensen
AAAS Congressional Science Fellow
Office of Senator Dianne Feinstein
Washington, DC

Ed Geary
Program Director
Division of Research on Learning in Formal and Informal Settings
National Science Foundation
Arlington, VA

Monique Chyba
Assistant Professor
Mathematical Sciences
University of Hawaii
Manoa, HI

Sherry Blunk
Doctoral Candidate
Biological Systems Engineering
University of California
Davis, CA

Laura Conner
Director of Outreach
College of Natural Science and Mathematics
University of Alaska
Fairbanks, AK

Tapas Das
Professor
Industrial and Management Systems Engineering
University of South Florida
Tampa, FL
Linda George  
Professor  
Environmental Sciences and Management  
Portland State University  
Portland, OR  

Melissa George  
Albert Einstein Distinguished Educator Fellow  
National Science Foundation  
Arlington, VA  

Rosemary Gillespie  
Professor and Schlinger Chair in Systematic Entomology  
University of California Berkeley, CA  

Anant Godbole  
Professor  
Department of Mathematics and Statistics  
East Tennessee State University Johnson City, TN  

Cynthia Godoy  
Math and Science Teacher  
Stevenson Middle School  
Los Angeles, CA  

Holly Godsey  
Manager, Formal Science and Math Education Programs  
Center for Science and Math Education  
Assistant Professor, Department of Geology and Geophysics  
University of Utah Salt Lake City, UT  

Aimee Govett  
Associate Professor  
Science Education  
Department of Curriculum and Instruction  
East Tennessee State University Johnson City, TN  

Phil Henning  
Adjunct Professor  
Department of Integrated Science and Technology  
James Madison University Harrisonburg, VA  

Susan Hillman  
Professor  
Department of Education  
University of New England Biddeford, ME  

Michael Jacobson  
Professor  
Department of Mathematical and Statistical Sciences  
University of Colorado Denver Denver, CO  

Larry Joh  
Academic Coordinator  
College of Engineering  
University of California Davis Davis, CA  

Larry Johnson  
Professor of Veterinary Integrative Biosciences  
Texas A & M University College Station, TX  

Pauline Johnson  
Professor  
College of Engineering  
University of Alabama Tuscaloosa, AL  

Vikram Kapila  
Professor  
Department of Mechanical Engineering  
Polytechnic University of NYU Brooklyn, NY  

Alexandra Lau  
Graduate Student  
Department of Mathematics  
University of Hawaii at Manoa Manoa, HI  

Kam Leang  
Associate Professor  
Department of Mechanical Engineering  
University of Nevada Reno Reno, NV  

Ami LeFevre  
Science Teacher  
Niles West High School Skokie, IL  

Joceline Lega  
Professor  
Department of Mathematics  
University of Arizona Tucson, AZ  

Doug Levey  
Program Director  
Division of Environmental Biology  
National Science Foundation  
Arlington, VA  

Henrietta List  
Program Manager  
SPARTACUS GK-12 Project  
University of New England Biddeford, ME  

Donna Llewellyn  
Associate Vice Provost for Learning Excellence  
Director  
Center for the Enhancement of Teaching and Learning  
Georgia Institute of Technology Atlanta, GA  

Michael Magee  
Graduate Student  
Brooklyn College CUNY Brooklyn, NY  

Pat Marsteller  
Director  
Center for Science Education  
Emory University Atlanta, GA  

Ana-Rita Mayol  
Director of Special Programs  
Office of the Dean  
College of Mathematics, Natural Sciences & Technology  
Delaware State Dover, DE  

Richard McCourt  
Program Director  
Division of Graduate Education  
National Science Foundation  
Arlington, VA  

Karen McNeal  
Associate Professor  
Department of Geosciences  
Mississippi State University Mississippi State, MS
Maria Modelska
Civil and Environmental Engineering Department
Rice University
Houston, TX

Mark Nanny
Boggs Professor of Engineering Education
School of Civil Engineering and Environmental Science
University of Oklahoma
Norman, OK

David Oberbillig
Albert Einstein Distinguished Educator Fellow
Department of Energy
Washington, DC

Sonia Ortega
Program Director
Division of Graduate Education
National Science Foundation
Arlington, VA

Melissa Page
Evaluator
G-Teams Program
University of Arizona
Tucson, AZ

Michelle Paulsen
Program Director
Reach for the Stars GK-12
Northwestern University
Evanston, IL

Diana Pietro
GK–12 STARS Project Manager
University of South Florida
Tampa, FL

Barbara Plonski
Director of School Services and Advancing College Readiness
Mass Insight Education
Boston, MA

Calvin Pohawpatchoko
Graduate Student
ATLAS Institute
University of Colorado
Boulder, CO

Kevin Powell
G-TEAMS GK-12 Fellow
Department of Mathematics
University of Arizona
Tucson, AZ

Susan Powers
Spence Professor of Sustainable Environmental Systems
Clarkson University
Potsdam, NY

Sarah Radencic
Project Coordinator
INSPIRE GK-12
Mississippi State University
Mississippi State, MS

Julie Rodriguez
Project Manager
Transforming Experiences GK-12
University of Colorado Denver
Denver, CO

Don Roth
Professor
Department of Molecular Biology
University of Wyoming
Laramie, WY

Megan Schnorenberg
Coordinator
Science Posse
University of Wyoming
Laramie, WY

Eric Simms
Academic Coordinator
Scripps Institution of Oceanography
University of California San Diego
San Diego, CA

Lesley Smith
Outreach Scientist
Cooperative Institute for Research in Environmental Science
University of Colorado
Boulder, CO

Anna Stewart
PhD Student
State University of New York
College of Environmental Science & Forestry
Syracuse, NY

Kate Stoll
AAAS Science & Technology Policy Fellow
National Science Foundation
Arlington, VA

Richard Tankersley
Professor
Department of Biological Sciences
Florida Institute of Technology
Melbourne, FL

Beth Todd
Associate Professor
Department of Mechanical Engineering
University of Alabama
Tuscaloosa, AL

Jan Truchot
Program Coordinator
Science Posse
University of Wyoming
Laramie, WY

Stephan Zeeman
Professor
Department of Marine Sciences
University of New England
Biddeford, ME

Tim Spuck
Albert Einstein Distinguished Educator Fellow
National Science Foundation
Arlington, VA