girls in science
Girls in Science

A Framework for Action

By Liesl Chatman, Katherine Nielsen, Erin J. Strauss, and Kimberly D. Tanner

with J Myron Atkin, Marjorie Bullitt Bequette, and Michelle Phillips
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ABOUT THE AUTHORS

Authors

Elizabeth (Liesl) S. Chatman
   Director of Professional Development
   Science Museum of Minnesota

Katherine Nielsen
   Co-Director, Science & Health Education Partnership (SEP)
   University of California at San Francisco

Erin J. Strauss
   Professional Development Project Lead
   Science Museum of Minnesota

Kimberly D. Tanner
   Assistant Professor of Biology
   San Francisco State University

All of these authors contributed equally and are listed in alphabetical order.

Contributors

J Myron Atkin
   Professor Emeritus of Education
   Stanford University

Marjorie Bullitt Bequette
   Professional Development Project Lead
   Science Museum of Minnesota

Michelle Phillips
   Evaluator
   Inverness Research
INTRODUCTION

This book is about promoting gender equity and, beyond that, equity on a larger scale within science education. It is for anyone who is engaged in science teaching: school teachers, professors, museum educators, school volunteers, and professional developers, to name but a few. The ideas, models, and voices contained herein come out of an extended professional development effort, known as Triad, that took place in San Francisco with funding from the National Science Foundation.

The Triad Framework for Equitable Science Teaching that emerged from the Triad community of practice serves as the architecture of this book. Encapsulating the influences, goals, and strategies that we found useful and further developed, the Framework is a conceptual tool that helped us analyze our work from three standpoints: students, teaching, and science. It has encouraged us to be mindful of many different levels of promoting equity within science teaching. The Framework began in graphic form, and its organization around the nodes of students, teaching, and science has enabled us to take those findings from relevant research on gender equity, teaching and learning, and science education that had the most profound impact on our thinking and to integrate and translate the findings into concise goals. These goals, in turn, were given life through the articulation of concrete, meaningful behaviors and teaching strategies. The Framework is the conscience of this book.

The heart of this book lies in the experiences of the people in the Triad community of practice. Our community included teachers, scientists, professional developers, students, and evaluators; each is given voice through the use of minicases or, as we refer to them throughout: vignettes. These vignettes are culled from first-person narratives, excerpts of transcripts from Triad’s qualitative evaluation effort, and program records of events involving Triad students, teachers, and scientists. They are brief, often full of conflict and inner tension, and, at times, might feel to you, the reader, like passages from a story or fragments from an overheard conversation. Our hope is that the open-ended and ambiguous nature of the vignettes coupled with the accompanying questions for reflection will cajole and provoke you into new insights and greater depth.

This book supports professional development. Throughout the evolution of our work, we’ve defined professional development as the process of becoming the professional each of us wants to be. The foundation of our approach to professional development is the conviction that our beliefs as teachers are intimately tied to our actions—and vice versa—and are therefore central to any effort directed toward positive changes in teaching practice. It is through the analysis of our beliefs and our own practices that we as teachers give substance, depth, and consistency to the improvements we try to
make in our work with students. Although it can be done individually, analysis and reflection of this kind often benefits from opportunities to consider the beliefs and actions of others in a collegial and supportive environment. As this book unfolds, the great extent to which we have interwoven practice, professional development, and evaluation will become self-evident.

This book is the story of one community. The Framework with its goals and strategies, the research cited, and the vignettes have all been used by our community and have proven themselves to be valuable. We hope they will be just as valuable to you.

A Book With Many Entry Points

Because we ourselves—even when we care deeply about a given subject manner—don’t always have the time or the inclination to read an entire work of nonfiction from start to finish, we wanted this book to be usable in both a linear and a nonlinear fashion. You can pick it up and read it straight through, cover to cover, or plop it open to a page and dive in. This dive-in is particularly feasible in Chapters 3, 4, and 5. We are indebted to the authors of the Birders Handbook (Erlich et al. 1988) for inspiring this approach and to the creators of the Project 2061 Atlas of Scientific Literacy (AAAS 2001) for one of the most magnificent uses of purposeful graphic organization ever to grace the pages of science education literature.

Our text is written in three sections. Section I tells the story of the Triad community, its context, and the struggles that resulted in growth (Chapter 1) and then provides an overview of the Framework (Chapter 2). If you are linear, love stories, and like a lot of context, this is a great place to start.

Graphics and Iconography: Section II is organized around the Triad Framework for Equitable Science Teaching and its iconography. If you are a visual learner and approach books nonlinearly, this iconography will orient you to where you are and guide you to places of interest. From its earliest stages of development, the Framework was conceived and enacted in graphic form. Think Venn diagrams. The Venn diagram in Figure A is the first form of representation of the Framework and refers to students on the upper left, teaching on the upper right, and science on the bottom center. The origins of the iconography are described in Chapter 2. We’ve used this iconography and related graphics throughout this book because we all believe that thinking and understanding in many forms—text, symbols, illustration, and graphics—helps us to think and understand better. As Elliot Eisner puts it:
The selection of a form of representation is a choice having profound consequences for our mental life, because choices about which forms of representation will be used are also choices about which aspects of the world will be experienced. ... Thus the paradox: A way of seeing is also, at the same time, a way of not seeing. (2004)

We've used the icon in Figure A to orient what you’re reading to the Framework. We’ve also annotated links to other pages and chapters to help you find related topics of interest.

**Essays and Research:** Research that had profound influences on our work is described in detail in the essays found in Chapters 3, 4, and 5. These three chapters are organized around the nodes of the Framework: Student Goals (Chapter 3), Science Goals (Chapter 4), and Teaching Goals (Chapter 5). As best we can, we’ve made efforts to introduce the reader to specific researchers and to point to their research articles—however, we want to make clear that our intent is not to present a meta-analysis or a comprehensive literature survey of research in all the fields related to gender, pedagogy, and science education. It is our intent to support our abilities to translate the ever-dynamic body of research into effective practices; our primary audience is the practitioner (and we include ourselves in that category).

**Vignettes:** The vignettes, described earlier in the introduction, are clustered around the goals of the Framework and accompanied by an essay also specific to a given goal. Our hope is that the vignettes will engage you in thinking about and discussing the dilemmas inherent in equitable science teaching. Each is accompanied by a set of questions for personal contemplation or communal discussion. The questions reflect the issues we grappled with as a community. We still wrestle with them. We invite you to use them in professional development contexts as well and have included more information about their use in Chapter 6 and Appendix A.

Our approach to writing this book has been to invite the reader to make the ideas presented herein your own and to remain true to the spirit of a dynamic and ever-evolving approach to teaching and learning. We're honored to have you join us in that process.
SECTION I

The Triad Story and Framework
CHAPTER 1
The Triad Story—A Science Education Community Navigating Gender Equity

Our efforts emerged from the backdrop of the science education reform movement in the 1990s. Then and now, a host of public policy documents and reports have elucidated the need for better education in the quantitative disciplines of science, technology, engineering, and mathematics (STEM). It becomes clearer and clearer that for economic health, the United States needs a larger and more diverse domestic STEM workforce. For everyday problem solving, scientific thinking is invaluable. For responsible citizenry in a world increasingly dominated by technology, scientific literacy on the part of the public is vital. These are some key rationales.

Yet, due to an array of factors, girls and women are still being steered away from STEM pursuits. In K–12, boys tend to be more confident about their math and science abilities than girls (Linn and Hyde 1989; Libarkin and Kurdziel 2003), and at an early age girls are more likely to develop negative attitudes toward science, resulting in self-doubt in their abilities (Steinke 1999). Girls often internalize disabling stereotypes, including the belief that computers, technology, and science are masculine and that there is a biological explanation for boys performing better in science, math, and technology (Gatta and Trigg 2001). In traditional K–12 science and math classroom environments, girls exhibit less self-confidence and are less assertive than boys (AAUW 1992; Fenema 2000). Boys tend to dominate discussions and interrupt girls and are more likely to be in physical possession of hands-on educational materials (Holden 1993). This environment is maintained by teachers’ behaviors: Teachers ask higher-order questions of boys, are more likely to call on boys first, give boys more praise and substantive feedback, and, given the same task, will provide instructions for boys but show girls how to do it (Tobin and Garnett 1987). As a consequence, in K–12 STEM classes, boys are more likely than girls to have experiences with materials, experiences in problem solving, and opportunities to process these experiences through verbal communication, extensive acknowledgment, and feedback.

In high school, key issues expand to include course-taking patterns and lowered performance on national tests. For many African Americans, women, and members of other marginalized groups, stereotype threat around STEM raises anxiety and can affect negatively performance on exams, leading to avoidance of mathematics, sciences, and engineering (Adler 2007). Females continue to be underrepresented in advanced courses
in both math and science during high school (AAUW 1998; NCES 2002), and females are more likely than males to stop taking mathematics courses after Algebra II. It makes sense, then, that males continue to receive mathematics and science honors and awards more frequently than females (Science Service 1998) and that females continue to score lower on the mathematics portion of the SAT college entrance exam (AAUW 1998). Similar gender differences are found in ACT and advanced placement mathematics and science test results (AAUW 1998). Moreover, these issues are compounded by race, ethnicity, class, and culture. Students of color are less likely to enroll in higher-level math courses, leading to an exacerbated and persistent gender achievement gap in K–12 mathematics within some racial and ethnic groups (Catsambis 2005).

At undergraduate, graduate, and postgraduate levels, fewer women than men enter college with an interest in pursuing science and engineering. In 2004, 26% of female first-year students intended to major in a science and engineering field versus 41% of males. By the time students reach graduate school, women earn only 34% of doctorates in science and engineering (Libarkin and Kurdziel 2003), and in 2004 women earned approximately 25% of computer science and information science undergraduate degrees and only 23% of the doctoral degrees (NSF 2007). These disparities manifest themselves in the workforce. In 2003, 28% of employed physical scientists and only 11% of employed engineers were women (NSF 2007). Women are also greatly underrepresented in information technology, systems analysis, software design, programming, and entrepreneurial positions (AAUW 2000). Some insist that a gender gap in science, technology, engineering, and mathematics no longer exists; the evidence indicates otherwise.

The Story of the Triad Community
Against this backdrop of inequity, the Triad effort began as a gender-equity initiative in San Francisco with funding from the National Science Foundation. Through Triad, teachers from the San Francisco Unified School District (SFUSD), scientists from the University of California at San Francisco (UCSF), and partnership specialists from the UCSF Science and Health Education Partnership (SEP) joined forces to understand and improve gender-equity dynamics in the local schools. Triad was so named because we sought to have a positive impact on three groups: scientists, teachers, and students.

Before we describe the Triad program, situating the effort within its organizational home, the UCSF SEP, will be helpful. Initiated in 1987 by UCSF Professor Bruce
Alberts, SEP is a longstanding partnership between UCSF and SFUSD. The specific mission of SEP is to promote partnership between scientists and educators in support of high-quality science education for K–12 students. To these ends, SEP develops and implements programs that support mutual teaching and learning among teachers, students, and scientists; promote an understanding of science as a creative discipline, a process, and a body of integrated concepts; contribute to a deeper understanding of partnership; and provide models and strategies for other institutions interested in fostering partnerships between scientific and education communities. The UCSF SEP has created several integrated models of partnership and more than a dozen programs that engage hundreds of scientists and teachers on an annual basis in 80% to 90% of the public schools in San Francisco. Triad, though, was the first SEP professional development project to address squarely issues of access and equity in science education.

In 1994, when Triad began, the program staff, teachers, and scientists came together because we shared a belief that science—its knowledge, culture, and habits of mind—belongs to everyone regardless of gender. Our initial approach was to bring together middle school girls, teachers, and scientists in a network of school-based girls science clubs. Our idea was to engage teachers and scientists in professional development, and they, in turn, would cosponsor science clubs and use these strategies in their club activities. We wrote a proposal around this concept, and in 1994 the UCSF SEP received an award through the NSF Experimental Program for Women and Girls (EPWG) to develop the Women’s Triad Project, with Liesl Chatman serving as principal investigator. After-school Triad clubs were active in San Francisco’s public middle schools and coauthored by teams of women teachers and scientists at the school site. Over the course of the next decade, the Triad effort expanded significantly in its approach, endeavoring to translate research into practice and, in the process, developed the Triad Framework for Equitable Science Teaching.

Initial Community Struggles
In the early years of our effort, we knew there wasn’t equal access to science for all students and that gender featured in this inequity. We were committed to opening the doors to science, but changing the equity dynamics we’d grown up with was a big task. We read the research on gender and science, invited speakers from all over the country to come and share their expertise, and invested personal time and energy in engaging middle school girls in science learning through club activities. It didn’t take long before we realized that meeting weekly with girls science clubs, making liquid
nitrogen ice cream, and building bird houses just wasn’t going to be enough. The problems that kept girls from being engaged and successful in science classrooms were too complex for a simple after-school science club to fix. As the Triad teachers and scientists worked with their science clubs and gathered with one another to learn more about gender equity issues in science education, they continued to say, “We understand the problems described in the research, and these problems are not going away. What can we do?” Clearly just knowing the research wasn’t enough; more steps were necessary. We needed to move from having fun to being thoughtful. We needed to translate research findings in gender equity into explicit, concise goals and teaching strategies that our community could use. We needed to shift the focus from students to ourselves and our own teaching behaviors.

From Research to Practice
The Triad staff gathered in the fall of 1997 to discuss the development of specific, research-based goals. Because the program was about encouraging girls in science, we decided to begin with goals for girls. What did the research and our own experiences tell us were particular concerns? What would a girl who was strong in science look like? What kinds of intellectual and emotional resources would she have? She would be confident enough to explore on her own and with others. She would see confusion as an opportunity to learn and would have the persistence to work through problems. Failed experiments would provide information to this resilient girl; problem solving would be intriguing rather than defeating. She would use evidence to form and support her positions and would then have the courage not only to voice her opinion but also to address challenges to it and disagree with others. She would know how to use a variety of tools—both scientific and everyday—to explore and manipulate her world. Through this emerging vision, we distilled a set of Girl Goals (later referred to as Student Goals). In order to keep them accessible and memorable, we made them short and crisp. Girls would possess

- Confidence to Explore
- Familiarity With Tools
- Persistence Through Confusion
- Resilience to Failure
- Defending a Position with Evidence

The Triad community took these Girl Goals, which will be introduced in Chapter 2 and detailed in Chapter 3, and began to work with them in the context of science
clubs and professional development workshops. We asked ourselves what kinds of experiences girls need in order to develop these traits, and with these discussions moved from activities that were fun and engaging to activities that were fun and engaging and purposeful in supporting the Girl Goals.

Clubs Begin to Evolve

With these new Girl Goals, things began to change. For example, science clubs had often done engineering activities, but now teachers and scientists were modifying those activities and experimenting with their own teaching in light of the goals. One such instance was modifying an activity centered around making bridges out of drinking straws and straight pins. In general, the initial challenge was, “Whose bridge can hold the most weight?” The lesson was structured around competition, but there was no particular attention paid toward instilling scientific or engineering habits of mind. Part of engineering is about testing designs in failure mode; it is important to know when and how things fail. The example of the Interstate 35W Bridge collapse in Minneapolis in 2007 tragically underscores this point. In Triad professional development and then in clubs, the bridge-design activity started changing so that the challenge became to test bridges in failure mode, to redesign them, and to increase the success rate of the bridges with respect to weight bearing across a given span. All girls had the opportunity to see their bridges fail, addressing the Girl Goal of resilience to failure. And all the girls had the experience of using this failure to make structural improvements in their bridges.

Real change, though, is not simple. It wasn’t enough just to think about the girls and to modify the kinds of activities they did in the clubs. Girls spent the majority of their time in coed classrooms. The Triad science clubs needed to become environments in which the interactions between teachers and students and between scientists and students were just as critical as the activities undertaken. And our own interactions with students, again, often mirrored the inequitable behaviors described in the research literature. Concurrent with these realizations, many of the clubs went from being just for girls to being coeducational, spurred by California initiatives in the 1990s in affirmative action measures based on race, ethnicity, and gender. In the coeducational settings, problematic interaction patterns were even more evident. The teachers and scientists needed to change, but how? Our professional development needed to change, but how?

We began to regard our science clubs as equity teaching laboratories. Translating research into equitable practices in the context of coeducational instruction became
the heart of our second proposal to the NSF, which was funded in 1998. The objectives of this broader effort, known as the Triad Alliance for Gender Equitable Teaching, were to develop a professional development program in gender equity and undertake a comprehensive research, documentation, and dissemination effort. This book is the fruit of that labor. The goals of the professional development program in gender equity were to

- engage teacher and scientist partners in iterative professional development focused on implementing equitable teaching strategies and engaging in reflective practice,
- develop a cadre of gender-equity leaders and mentors in the public school and the university, and
- enable teacher and scientist partners to pursue research into the effectiveness of their gender-equity efforts on girls.

Our team was joined by J Myron (Mike) Atkin, Professor of Science Education, Stanford University School of Education, who led our external evaluation group. Little did we know how profound the collaboration between our team of evaluators and professional developers would be.

**We All Have to Change**

One evening at a Triad professional development workshop in the first year of the second award, the adults were reflecting on their progress. The program staff was concerned about what we saw out in the clubs and began to question the efficacy of our own efforts. At the workshop, the team began to ask hard questions about how we all as adults were still inadvertently disempowering girls: “We’ve tried to provide the translation from research to practice you’ve been asking for. We’ve modeled pedagogical strategies. We’ve created concrete Girl Goals. But when we visit the science clubs, we still see patterns of interactions that foster inequities and limit access to rich science learning experiences for girls. Adults are taking materials out of girls’ hands. Dominant girls are driving the group work. There seems to be more concern about girls having right answer than experiencing science in all its messiness. What’s going on?” It was a tense moment for everyone, but the group members were committed to one another and to our work. As we talked, it became clear that we needed to discard the pernicious notion that someone was going to give us a magic bullet that would fix everything. In our Greek tragedy, there was no deus ex machina to come down and fix everything. “That’s why we have a federal grant: because we are creating solutions that no one has come up with.” We were
CHAPTER I: The Triad Story

the ones we were waiting for. That evening marked a turning point.

One club went back and videotaped a meeting and let students watch their own interactions. The club’s scientist-teacher team then let the rest of us watch the video. We were all disturbed by what we saw. In one memorable scene, which involved making and testing small cars, the girls in one group sat silently with pieces of tape stuck on their fingers for the boys to use. The girls had become human tape dispensers. It was a rude awakening to us all. We had made progress through working with the Girl Goals, but it wasn’t enough. It wasn’t enough to talk about familiarity with tools. We needed to create an environment in which the tools stayed in the girls’ hands.

Developing strong girls was not just about the girls; it was also about every one of us—the adults who worked with the girls—changing our own attitudes and teaching behaviors as well. Yet we had great difficulty combing the research to find out how to go about it. Yes, there was a wealth of resources, but to make the translation from research to practice was a monumental task. Strategies were spread far and wide, embedded in articles, written for the researcher and not the practitioner, and often described methods that were sufficiently complex to be impractical for an inner-city class of 40. Real change was up to us. If the girls in Triad were going to develop in the ways outlined in the Girl Goals, we adults needed some Teaching Goals of our own. As adults, we had to believe and expect that every one of the girls could become confident, persistent, and resilient. This meant we would have to let them explore, struggle with confusion, and even fail at some tasks. We had to trust the girls to ask important questions and do meaningful work; we had to let the girls be leaders. And, finally, we had to address our own fears and discomfort about talking explicitly about equity. We had to talk with one another about our own behaviors as adults; we had to talk with the girls about group dynamics in the clubs; and we had to take some club time to talk about society at large and what the girls saw and experienced in their schools, neighborhoods, and homes. Again, we distilled a set of goals for ourselves, a set of Teaching Goals, which will be introduced in Chapter 2 and detailed in Chapter 5:

- Encourage Student Voices
- Maintain High Expectations
- Delegate Responsibility
- Make Equity Explicit
- Reflect to Improve Practice

Again we pored over the research. And again the clubs changed. Our own actions changed as well. As a community, we were taking responsibility for figuring out
where we needed to go next and how to get there. The goals quickly translated into teaching strategies that, in turn, became rallying cries. “Keep your hands in your pockets!” “Answer questions with questions!”

But What About the Science?
Fortunately, Triad had keen and thoughtful observers—our evaluators from Stanford University, Mike Atkin and his team of doctoral students, who had joined us with the new grant. The evaluation team members were an integral part of our community and very supportive of the work Triad was doing. They spent many hours watching and recording what happened in adult meetings and in clubs and thinking deeply about implications. At our end-of-the-school-year evaluation retreat in 1999, they came to the staff with a critical observation. They noted that it was great that Triad had Girl Goals and Teaching Goals, but this project was about girls in science. The evaluation team was observing lots of growth on the part of all the participants, but the science itself still seemed to be about fun. Now fun is grand—but shouldn’t the girls, asked the evaluation team, be developing scientifically as well? In a fashion similar to those that had preceded it, the pendulum swung, and we began the process of creating Science Goals.

Although it may seem as though the Science Goals would have been the first and the easiest to develop, that was not the case. Partly, this was an issue of professional cultures and partnership. Triad brought classroom teachers who were responsible for teaching a wide sweep of science ideas together with scientists who were specialists in areas like neuroscience or cell biology or biomedical engineering. The cultures of their professional worlds were quite different, and agreeing on what was most important for girls to know about science was not an easy task. (For a detailed perspective on these professional cultural issues, see Tanner et al. 2003.)

By this time, the entire Triad community was working to refine the goals and associated strategies. Veteran participants had joined the staff in designing and conducting professional development. We re-read national standards documents and poured over the hot-off-the-press Inquiry and the National Science Education Standards (NRC 2000), which several of our good colleagues were involved in. By engaging in joyous and thunderous debates and trying on many versions of language, the community finally agreed on a set of goals—and then completely revamped them the following year! We came to consensus that what was common to all science were ways of thinking and doing that resulted in new understanding grounded in evidence. Clubs
might explore many different kinds of science topics, but in every club girls should be thinking and acting scientifically. They needed to work in community to build their knowledge and skills; they needed to do experiments rather than just watch or hear about them; they needed to develop scientific habits of mind; they needed to experience the natural world as a source of wonder; and they needed to learn how to use evidence to make predictions, explain phenomena, and develop models. In the end, we distilled a set of Science Goals, introduced in Chapter 2 and detailed in Chapter 4, that had great traction:

- Wonder About the Natural World
- Do Science to Learn Science
- Think Critically, Logically, and Skeptically
- Use Evidence to Predict, Explain, and Model
- Build a Community of Scientists

With this final goal set, the Triad Framework emerged.
CHAPTER 2
The Triad Framework—A Tool for Discussing Gender-Equitable Science Teaching

In chapter 1, we described Triad and the Framework from a community perspective. In this chapter, we’ll describe how the Framework evolved from a more theoretical standpoint. We’ll introduce its anatomy and initiate a more detailed discussion of its goals and the research that informed them. Right up front, we need to be clear that the Framework is intended to be dynamic and not definitive—a point we will return to at the end of the chapter.

Evolution of the Framework

The Graphic Story
As Triad came into being in 1993–1994, we wanted a name that would let people know that our community had three types of people—teachers, scientists, and kids—and that we had learning goals for each. So the name Triad was coined, and the initial graphic representation of the Venn diagram of three circles (Figure 2A) soon followed. This schematic, though, first came to us through a chalkboard talk at Berkeley’s Lawrence Hall of Science from Larry Lowrey, professor emeritus of the University of California at Berkeley and the principal investigator of the Full Option Science System (FOSS) in the early 1990s. He used this Venn diagram to describe the knowledge arenas needed for effective science teaching: knowledge of students and learning, knowledge of effective teaching methods and pedagogy, and knowledge of the discipline of science. Its elegance has proven extraordinarily helpful, and you will see us use it as an über-organizing feature of this book. Within the Triad program, we consistently presented the icon in color, using the primary colors of light: green, blue, and red. We did this because, when all of the colors in light are combined, there is total illumination. It is a metaphor for our aspirations.
Triad’s Theory of Action and the Goal Sets

As our story in Chapter 1 evidences, as a community we struggled with how to translate research into tangible actions that educator scientists could practice with students. Knowing the research helped us to be aware of the problem of gender inequity, but it didn’t automatically help us to see interaction patterns or to help us change our own behaviors. Our theory of action was that engaging teacher and scientist partners in a professional development cycle of preparation-action-reflection, based on clear equity goals, would enable us to increasingly implement equitable teaching strategies and reflect on our practice. First articulated in our renewal proposal to NSF in 1998, this theory of action was greatly influenced at the time by the work of Susan Loucks-Horsley and colleagues in their book *Designing Professional Development for Teachers of Science and Mathematics* (Loucks-Horsley et al. 2003).

Goals were fundamental to this process. Did we prepare lessons based on equity goals? Did we put them into action? What did we find when we reflected back on the extent to which we met our goals? We found that when we distilled our goals into easily remembered nuggets around the nodes of the Framework—student goals, teaching goals, and science goals—we got more traction in positively changing our actions and behaviors and the capacity to see and reflect. Thus, for each of the three nodes, we articulated a goal set. Each goal set includes four or five brief phrases that helped us to maintain a tight focus on behaviors and attitudes—such as the Student Goal, Persistence Through Confusion—that our work revealed were critical.

A Word About Grain Size

As we worked through creating the framework, levels of complexity and detail emerged at each step as we established clearer and clearer targets of what gender-equitable teaching and learning might look like. We came to think of these layers as grain-size issues. We used three basic “grain” sizes, analogous to rocks, pebbles, and sand. The largest grain size, that of rocks, is the goal set—the Student Goals, Teaching Goals, and Science Goals seen in Figure 2B—in the three major areas of students, teaching, and science. The goal set helps us to tease out questions such as “Are we talking about behaviors and attitudes linked to students and learning, to teachers and pedagogy, or to scientists and the scientific endeavor?” Within each goal set, the next-smaller “grain” size, that of pebbles, is the individual goal within the goal set. At this level, we ask, “What is the compelling argument that this is a gender-related issue?” Thus, we are concerned with relevant research and the rationale as to why we have focused on a particular goal. Finally, the smallest here-are-some-specific-actions grain size, that of sand, is at level of the strategies related to
a given goal. These are the pragmatic actions that we can practice, the habits of mind that we can instill in ourselves and others, that turn research into practice.

This chapter deals with goal sets. Each of the three chapters in Section II addresses a goal set, and thus the discussions in these chapters will be at the level of the individual goals within the goal set and the accompanying exemplars/strategies. Section II is what we really consider to be the heart of the book; it’s where we’ll go into great depth, from theory to methods to implementation. These chapters will also include a collection of true vignettes that illuminate the complexities, challenges, and dilemmas of putting the ideas of the Framework into practice. These vignettes and where they came from are described in the introduction to Section II. Before we go there, it will be informative to return to the goal sets.

The Anatomy of the Framework and Key Research Influences

The Goal Sets
As we’ve indicated, for each of the goal sets mentioned above—students, teaching, science—the Framework assembles a group of concise goals to consider in promoting gender equity in science education. These goals were drawn from and synthesized by the Triad community from research, standards documents, effective-practices literature, and our own experience and data analysis. We wanted to find what specifically was key to changing the gender-equity climate in science classrooms. What were the problems we needed to address? The behaviors we needed to change? The attitudes we wanted to instill? The vision we intended to create?
Student Goals

As we began looking at the research in gender equity in the mid-1990s, over and over we saw descriptions of interaction patterns between teachers and students and between students and students that were mediated by gender. We saw that these interaction patterns restricted opportunities for girls that were key to science.

One of the fundamental aspects of the practice of science is its orientation around process. Our students need concrete, provocative experiences with materials in situations where they can express curiosity, explore natural phenomena, perform experiments, solve problems, and communicate observations, predictions, and conclusions. As they do so, they must persist through confusion, ask questions, and defend positions as they talk about science with their peers.

As we reviewed research, we found ample evidence that the prevailing culture of the middle school science classroom greatly restricts these experiences for girls. In a mixed-sex environment, boys express more self-confidence and assertiveness than do girls (AAUW 1992), are more likely to dominate discussions, to interrupt girls, and to be in physical possession of educational materials (Holden 1993). Hence, boys are more likely than girls to have concrete experiences in science and greater opportunities to problem solve, thereby fostering self-confidence and promoting a richer understanding of abstract concepts. Since self-confidence for all students is most closely linked to achievement in math and science (Linn and Hyde 1989), it is unsurprising, then, that middle school is the point at which girls’ confidence in science declines, followed by a decrease in interest and achievement (AAUW 1992). Our local data bore this out; statistical analysis of 6th- through 11th-grade scores on standardized math achievement tests (the 1996 Math Concepts and Applications portion of the Comprehensive Test of Basic Skills) showed that girls in the San Francisco Unified School District were not achieving at the same levels as their male peers.
Although a loss in confidence during the middle school years is a critical factor leading to reduced enrollment of girls in high school science electives, the problem is not limited to the adolescent period. As they continue their education through high school and into college, young women encounter the same cycle of discouragement. Even the female survivors who go on to graduate school and beyond frequently suffer with inappropriately low self-confidence and/or a low sense of efficacy. The attrition rate of females versus males in one UCSF research department evidences the disparity. Of the males leaving the department, 83% exited with a PhD while only 47% of the women did so. At the other end of the exit profile, only 10% of the men versus 26% of the women left with no graduate degree. For those who persevere at the graduate and postgraduate level, women scientists report setting less ambitious goals than their male counterparts, and they are also less likely to be in positions of leadership in the scientific community (Vetter 1992). The ultimate effect is that females are strained through an increasingly fine mesh that separates the discouraged from the few who still have their confidence intact.

Thus, the student goals (see Figure 2C) are rooted in the predispositions and metacognitive skills needed in science. However, they go beyond standards documents and are informed by research in education, sociology, and gender studies. They are intended to promote the internalization of attitudes and actions, such as resilience and effort, that are vital to science but, research indicates, aren't fostered in girls. They point out the ways that individuals should engage in science but, because of gender-based interactions, don't.
provide instructions for boys but show girls how to do it (Tobin and Garnett 1987). Even though girls are less likely to interrupt, if they do, we're more apt to reprimand them. We tend to give girls less critical feedback—at worst we give them irrelevant feedback like “Neatly done!” accompanied by a smiley face regardless of the quality of their work, good or bad. Girls are also likely to talk at a less-abstract level in coeducational groups (Martinez 1992). In our efforts to be sure students do it “right,” we hover and rescue (Cohen 1994; Gordon 1995), usurping their sense of authority and efficacy. We ask a simple question, immediately call on the first hand raised (usually a boy), and then lament that other students aren’t participating. It takes conscious and focused effort for us to change these patterns. Those of us who are postsecondary science educators usually have no training in educational strategies; we often unwittingly repeat the same disparate treatment of males and females that students experience in precollege science education.

The teaching goals (see Figure 2D) help us to create a vision of the professionals we want to be. They are about facilitating student effort and apprenticeship, promoting and maintaining academic rigor regardless of gender, and being explicit about equity. Influences in this area included Mary Budd Rowe’s work on wait-time (1974), Paul Black’s emphasis on thinking about the questions we ask students (Black and Wiliam 1998; Black et al. 2004), Elizabeth Cohen’s explorations into delegating authority (1994), and, more recently, Lauren Resnick’s synthesis of a variety of research studies in “From Aptitude to Effort: A New Foundation for Our Schools” (1995).

Science Goals
The kind of in-depth inquiry called for in the National Science Education Standards (NRC 1996, 2000) and by Project 2061 (AAAS 1993, 2001, 2007) asks that learners engage in the habits of mind and authentic practices in which scientists engage. These documents make connections between the kinds of questions that scientists ask and the forms of investigations they use to address their questions and develop explanations. They emphasize data gathering, evidence, logic, analysis, and communication of results.

The Science Goals (see Figure 2E) are intended to encapsulate the discipline-based habits of mind used in science and are true to the intellectual intent and culture of science. They reflect the practices engaged in by practitioners both with respect to community structures and the authentic activities of scientists. Coupled with the Student Goals, they relate strongly with the essential features of classroom inquiry (NRC 2000):
Integrated Nature of the Goal Sets

Ultimately and collectively, the goals are about engaging all learners in science. The goals are formulated to be mutually supportive when integrated. For example, you may focus on the Student Goal of Defending a Position and the Science Goal of Use Evidence to Predict, Explain, and Model, and the Teaching Goal of Encourage Student Voices. These goals imply three things: one, that girls actually have evidence and know what constitutes evidence; two, that they take a position based on that evidence; and, three, that they have an opportunity to share their evidence and voice a position. You may then turn again to the Science Goals and see that Do Science to Learn Science sets the stage for experimentation and see that Use Evidence to Explain, Model, and Predict involves analyzing experimental data that will help students to formulate a position. Teaching Goals that will create opportunities to foster these behaviors are Delegate Responsibility and Encourage Student Voices. Delegating responsibility can be done by returning to the Science Goals and allowing groups of students to Build a Community of Scientists, designing experiments around a central topic or phenomena that collectively will produce a variety of results. Creating a forum for presenting their results and interpretation not only encourages student voices, it fosters Think
SECTION I: The Triad Story and Framework

Critically, Logically, and Skeptically as well. In this manner, the Framework is mutually reinforcing and can inform instructional decisions and practice.

From Goals to Actions: Strategy Exemplars

Finally, there is a last layer of graphic representation that looks like a flow chart. In Figure 2B, these are the smallest circles; in Figures 2F and 2G, they are the bullet points that relate to a specific goal. This layer of strategies creates a vision of ways...
of being, thinking, and acting in a science education environment. It is the heart of the translation from abstract to concrete, from theory to practice. For each goal, we articulated what we found to be a critical strategy, habit of mind, or behavior pattern that put flesh on the bones of a given goal. For example, it’s fairly easy to say, “I have high expectations of my students.” And we earnestly believe that we do. And yet, when we look at our actions, they betray us. We might give in when a student backs away from the equipment, expecting that we will rescue her by doing it for her. Our action, that of rescuing, conveys the expectation that she can’t do it.

A simple teaching strategy related to delegating responsibility, then, is to merely put one’s hands in one’s pockets as we talk to students who have questions about equipment. In this case, we delegate responsibility for doing the work to the student, maintaining the expectation that she can do it.

A Dynamic Translation Tool, Not a Definitive Collection

It is critical to understand from the outset that the goals and their related strategies are not intended to be definitive or exhaustive. They are—and thus the Framework is—a practical starting point, a tool to translate theory into practice, a way of moving from the abstract to the concrete. The Framework is an invitation to explore and purposefully change the interactions and behaviors in the science-learning environment to promote engagement of all individuals within that environment.

The original graphic used to describe our community evolved in Triad to have many functions. We first used it to describe our participants (teachers, students, and scientists). In time, our colleagues from Stanford who served as our evaluators used it as an organizing structure to assess our community’s progress. Ultimately, we used it to frame our goals. It’s important to remember that we took small steps to get there and that we didn’t have a clear vision in 1993 of where we were going. We only knew what our theory of action was, kept our eyes on solving the problem at hand, and acknowledged that no one had the magic bullet. We accepted that we were the ones we were waiting for.

The Triad structure has been harnessed by those of us who have used it to explore other content disciplines and other arenas of equity such as English language learning. And in the course of writing this book, we’ve refined the strategies, revisited research, reframed our discussions to address race, class, and culture, and through it all engaged in lively and healthy debates with each other.
SECTION I: The Triad Story and Framework

An Invitation
When we saw Pinky Nelson introduce the *Atlas of Scientific Literacy* (AAAS 2001) at the 2002 National Science Teachers Association’s national convention in Saint Louis, he invited the audience to sit down with the Atlas accompanied by a nice pen, a ruler, some Wite-Out, and good bottle of chardonnay. It was an invitation to make one’s own sense of the Atlas and a nod to the notion that there are many ways that concepts can be organized. We hope that you will do the same with Triad Framework—that you will morph these graphic tools into your own purposes and make them your own.
CHAPTER 2: The Triad Framework

Figure 21

Teaching Goals
- Encourage student voices
- Maintain high expectations
- Delegate responsibility
- Make equity explicit
- Reflect to improve practice

Science Goals
- Wonder about the natural world
- Do science to learn science
- Think critically, logically, and skeptically
- Use evidence to predict, explain, and model
- Build a community of scientists

Student Goals
- Confidence to explore
- Familiarity with tools
- Persistence through confusion
- Resilience to failure
- Defending a position

Gender-Equitable Science Teaching Framework
Student Goals and Strategies

Confidence to Explore
- wondering and tinkering
- trying new things and talking about my ideas
- knowing that I learn when I make mistakes

Familiarity With Tools
- exploring with materials in my hands
- learning what tools I need and how to use them
- using tools to build things and to accomplish my goals

Persistence Through Confusion
- remembering that confusion is part of learning
- asking questions when I don't understand or need more information
- trying a new strategy when a strategy didn't work
- understanding that most experiments need to be repeated

Resilience to Failure
- knowing that I learn when I make mistakes
- believing that I can influence what happens
- breaking big tasks down into smaller steps and learning how to minimize risk
- practicing and increasing effort

Defending a Position
- knowing it's important to test my ideas by sharing them with others
- talking about evidence when I present my ideas and explanations
- asking others for evidence when they state a position
- being willing to disagree with my classmates
Science Goals and Strategies

Wonder About the Natural World
Do Science to Learn Science
Think Critically, Logically, and Skeptically
Use Evidence to Predict, Explain, & Model
Build a Community of Scientists

Science Goals

- following my curiosity
  asking questions about the world around me
  thinking about what I already know
  wanting to find out more

- building my understanding through investigations
  exploring with materials
  recognizing investigable questions

- questioning conclusions and considering alternative explanations
  identifying and controlling variables
  organizing data and identifying patterns

- using what I see to make predictions
  identifying what evidence does and does not say
  using evidence to draw my own conclusions
  knowing the difference between observation and inference
  understanding that there are different kinds of models and that the model is not the real thing

- seeing myself as a scientist
  experiencing science as part of my daily life
  sharing and discussing findings with my classmates

Girls in Science
Teaching Goals and Strategies

- Encourage Student Voices
- Maintain High Expectations
- Delegate Responsibility
- Make Equity Explicit
- Reflect to Improve Practice

- using wait time structuring activities to engage all of my students in science talk
- planning specific strategies for small- and large-group discussions creating opportunities for my students to share/compare results

- answering questions with questions identifying confusing concepts and allowing my students to grapple with them providing opportunities for my students to practice involving everyone in giving and receiving substantive, critical feedback

- keeping my hands in my pockets giving my students open-ended tasks or challenges that have many solutions assigning and maintaining procedural roles

- learning to see inequity talking about what equity means and looks like exploring connections between beliefs and actions using equity strategies consistently and discussing them openly

- reflecting on the equity climate in my classroom integrating equity considerations into my lesson planning collecting and analyzing classroom evidence continually learning new things and using them to improve my teaching
SECTION II:
Exploring the Triad Framework Through Vignettes and Essays
INTRODUCTION

The Structure of the “Heart” Chapters
The purpose of this introduction is to prepare you to move quickly into the heart of this book: the voices of the Triad community and the depth of what we learned collectively about gender equity in science education. To illuminate these two pieces—voice and depth—we’ve used two elements: vignettes and essays. If you are using this book as an individual, this short chapter will serve as the platform for you to dive right in. If you’re using this book in the context of professional development programs, more detailed information about how to use the vignettes and essays is in Chapter 6 and Appendix A.

Rhythm: Essays and Vignettes
Each of the following chapters—chapters 3, 4 and 5—is organized around one of the goal sets of the Triad Framework for Equitable Science Teaching, as described in the previous chapters. The chapters are like musical measures. Each chapter includes a detailed overview of the goal set followed by a set of clusters around each goal. Each cluster contains two things: first, an essay on the goal, in which the goal is unpacked and connections are made to relevant research and policy that contributed to the formulation of the goal, and second, a set of brief first-person minicases—vignettes—that are related to the given goal. Each vignette is accompanied by set of reflection questions and links to related vignettes throughout the book. Lastly, we’ve used the Triad iconography described in Chapter 2 much as a field guides uses symbols to aid readers.

The vignettes are taken from a variety of written artifacts produced throughout the formal Triad program (see Appendix B for more information). In most if not all instances, they are vignettes from longer material produced by participants, staff, and evaluators. These vignettes have been pulled from first-person reports and reflections written at workshops and retreats, from transcripts associated with the qualitative evaluation conducted by the Stanford Evaluation Team, and from program records of events involving Triad students, teachers, and scientists.

The vignettes are intentionally brief and provocative, leaving many details vague or omitted. They are not developed cases but rather quick entry points into thinking or talking about tough, challenging topics because their ambiguity demands it. To foster contemplation, each of the vignettes is accompanied by several open-ended questions to prompt reflection and discussion. By grouping the vignettes into clusters, articulating reflection questions, presenting relevant information close by through essays, and including links to other related material, our hope is that we have made the material accessible to a broad variety of contexts and applications—and that it becomes personal.
Connections: Iconography and Links
The goals and strategies presented throughout this book are mutually reinforcing and highly interdependent. This is what gives them their power and coherency. In order to support an understanding based on this interdependency, we’ve used consistent structural devices and visual patterns to help you to snoop around out of sequence, to return easily to material you’ve already read, and to forge connections.

Figure A shows the general iconography for the Triad Framework as described in Chapter 2. This Venn diagram, in turn, is used throughout chapters 3, 4, and 5 with one difference: The specific goal appears in the corresponding goal circle. For example, the goal arena for Student Goals is always shown in the upper left of the Triad Venn diagram. One of the five Student Goals is Confidence to Explore. The icon shown in Figure B has the goal written in the upper-left sphere and will accompany any essay or vignette that is primarily related to the goal, Confidence to Explore.

The “Links” section follows the set of reflection questions for each vignette and refers you to other vignettes whose issues intersect with the one you’ve just read. In most cases, the links will take you to a different node of the framework and do so through the title of the related new vignette. This new vignette, in turn, will be nested within a goal with its own relevant essay.
CHAPTER 3:

Student Goals—Developing Girls Strong in Science
Student Goals and Strategies

Confidence to Explore
Familiarity With Tools
Persistence Through Confusion
Resilience to Failure
Defending a Position

- wondering and tinkering
- trying new things and talking about my ideas
- knowing that I learn when I make mistakes

- exploring with materials in my hands
- learning what tools I need and how to use them
- using tools to build things and to accomplish my goals

- remembering that confusion is part of learning
- asking questions when I don’t understand or need more information
- trying a new strategy when a strategy didn’t work
- understanding that most experiments need to be repeated

- knowing that I learn when I make mistakes
- believing that I can influence what happens
- breaking big tasks down into smaller steps and learning how to minimize risk
- practicing and increasing effort

- knowing it’s important to test my ideas by sharing them with others
- talking about evidence when I present my ideas and explanations
- asking others for evidence when they state a position
- being willing to disagree with my classmates
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CHAPTER 3: Student Goals

The Triad Student Goals—initially born as Girl Goals—were crafted as a tool to aid teachers and scientists in designing science club activities that went beyond fun. In the early years, there was a sense that simply having female scientists, female teachers, and female girls all in the same room doing science together and enjoying it would encourage girls in science. But we came to feel that having fun doing science was not enough. The literature on gender equity in education pointed to evidence that girls are often not given the opportunity to learn skills and habits of mind that are essential to being successful in science. We asked ourselves what traits are characteristic of students who enjoy science and are successful in science. Combining the teaching and scientific expertise from the Triad community with the findings in the literature, the Triad Student Goals were born. What emerged was a picture of a student who is confident in exploring the unknown, who is willing to ask questions, who is not wholly defeated by a wrong turn or a setback. This successful science student tends to persist through problems, confusions, and challenges and takes pride in her own ideas. She also has enough experience and familiarity with tools—both scientific and everyday—to use them confidently. No doubt there are other characteristics that could be listed and added to the Triad Student Goal set; however, these are the starting places that our community used to build strong girls prepared for the challenges and excitement of science. In the following pages, you will find a more detailed consideration of each of the Triad Student Goals—Confidence to Explore, Familiarity with Tools, Persistence Through Confusion, Resilience to Failure, and Defending a Position (See Figure 3A)—highlighting why each of these traits is important for success in science, why girls may have had fewer opportunities to develop these skills, what it might look like to achieve a given goal for a student, and some strategies for how to get there.

<table>
<thead>
<tr>
<th><strong>Triad Student Goals</strong></th>
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<tbody>
<tr>
<td><strong>Confidence to Explore</strong></td>
</tr>
<tr>
<td>• wondering and tinkering</td>
</tr>
<tr>
<td>• trying new things and talking about my ideas</td>
</tr>
<tr>
<td>• knowing that I learn when I make mistakes</td>
</tr>
<tr>
<td><strong>Familiarity With Tools</strong></td>
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<td>• trying a new strategy when a strategy didn't work</td>
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<td>• breaking big tasks down into smaller steps and learning how to minimize risk</td>
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<tr>
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<tr>
<td>• being willing to disagree with my classmates</td>
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Student Goals and Strategies

**Confidence to Explore**
- Familiarity With Tools
  - wondering and tinkering
    - trying new things and talking about my ideas
  - knowing that I learn when I make mistakes
  - exploring with materials in my hands
    - learning what tools I need and how to use them
    - using tools to build things and to accomplish my goals

**Persistence Through Confusion**
- Resilience to Failure
  - remembering that confusion is part of learning
    - asking questions when I don’t understand or need more information
    - trying a new strategy when a strategy didn’t work
    - understanding that most experiments need to be repeated

- Defending a Position
  - knowing that I learn when I make mistakes
    - believing that I can influence what happens
  - breaking big tasks down into smaller steps and learning how to minimize risk
  - practicing and increasing effort

- knowing it’s important to test my ideas by sharing them with others
  - talking about evidence when I present my ideas and explanations
  - asking others for evidence when they state a position
  - being willing to disagree with my classmates
Essay: Confidence to Explore

Fundamentally, science is about exploring and understanding the natural world. The process of being an explorer in science, as in any field, demands confidence: the belief in our ability to succeed through our efforts. Although there are maps to guide us in the form of information that has been drawn up by previous explorers—our fellow scientists—it is confidence that allows us to venture into uncharted waters. We need the self-assurance that we can go forth and return triumphantly. In these uncharted waters we not only discover new things, but we also see old ideas anew through our own eyes. Having the confidence to explore allows us to reinterpret evidence and contribute our own voice and vision to a problem or explanation. Without the confidence needed for exploration, we have little or no chance of making our own discoveries about the natural world around us. Whether we are at the top of our game as a world-renowned scientist or at the beginning as a grade schooler, it is the same act of courage.

In 1989, Marcia Linn and her colleague Janet Hyde performed a meta-analysis of gender differences in adolescence. What they found is that confidence is the principal trait for which gender differences do, in fact, exist (Linn and Hyde 1989). Elizabeth Fenema echoed this finding for girls’ confidence in mathematics (AAUW 1998; Fenema 2000). Myra and David Sadker documented that we adults can contribute to girls’ lack of confidence by stepping in and doing tasks for them, implicitly reinforcing that we do not believe they can do it on their own (Sadker and Sadker 1994). These rescuing behaviors by adults or more confident peers translate into fewer opportunities for some girls to explore, thereby diminishing their capacity to develop the confidence to be successful in science. Adults’ rescuing behaviors and the resulting lowered confidence can lead to a set of behaviors collectively referred to as learned helplessness (Peterson et al. 1995). In Judy Gordon’s work with Girls, Inc., she explored how a learned-helpless girl will give up at the first sign of difficulty (1995). She will sit back in expectation that the nearby adult or more confident peer will do it for her. She will say in the face of confusion, “I’m not good at that kind of thing,” or worse, “I’m stupid.” If confidence is key in science, then these self-reinforcing rescuing behaviors by adults in classrooms can result in learned helplessness that have academic consequences that are of particular concern for girls in science.

In science, students cannot gain the confidence to explore without ever having had the opportunity to explore. Learning situations in which students are rescued during an attempt to figure something out, in which there is a single answer expected from
SECTION II: Exploring the Triad Framework

an investigation, in which students most often follow prescribed directions during experiments, or in which unexpected results are ignored rather than celebrated and examined, all reduce opportunities for students to develop the confidence to explore. Learning situations in which students can defer to more confident classmates or get an adult to perform difficult parts of experiments for them do them a disservice.

Our task then as educators is to create learning environments in which students can develop confidence as they engage in science. A few ways to begin to achieve this are to

- provide ample opportunities for girls to investigate freely while pursuing science ideas. These experiences become true explorations when they are not externally prescribed by the teacher, a book, or a set of instructions. Much like practicing scientists whose confidence deepens with each discovery made, students’ willingness to try out their ideas can grow with each new exploration. This exploration, in turn, can be the basis for both new questions and greater understanding.

- respond to student questions with open-ended questions of your own. “How could we figure that out?” “How could we study it?” “What do you think?” “What do you think will happen if you try that?” This approach can help adults avoid the trap of intellectually rescuing students.

- promote girls’ belief that their efforts will result in increased skills and understanding. This is at the heart of confidence. In science, the act of exploration is, in and of itself, a form of success. Giving girls explicit positive feedback on the strategies they try and letting them know what they are doing is what scientists do can help girls develop an attitude of “I don’t know what to do next, but I’m confident I can explore more and figure this out.” That is the response of a student with the confidence to explore.
After the Initial Eeewwww

I thought I would discuss the heart and circulatory system on Valentine’s Day, which brought on the expected “awws.” I was unsure whether I should bring along the real specimens of the heart to display at the end of the club meeting, since I did not know how the kids would react. After getting input from my team members at our planning session, I conducted a straw poll at work among my colleagues (who even gave me input from their kids, similar in age to our club members), all of which persuaded me to take along a real heart to the club meeting. The consensus was that after the initial apprehension the kids’ natural curiosity would take over, but that we should definitely provide an out for the few who might not want to touch the specimen. I therefore decided to display the heart and then invite only those who wanted to touch it at the end of the meeting. I was surprised when after the initial “Eeewwww” everyone apparently wanted to poke their gloved fingers into the specimen, and this taught me yet another lesson.

Reflection Questions

- How did this scientist’s expectations of students influence their opportunity to explore during the lesson?
- How do your own expectations as a teacher influence your students’ opportunity to explore?
- In what ways did this scientist’s lesson actively not encourage students to explore?
- If you were doing this lesson, when would you have brought out the heart? Why?
- What are strategies for structuring lessons that encourage students to explore areas that may at first be intimidating to them? In what other ways might you build students’ confidence to explore?
SECTION II: Exploring the Triad Framework

Links

- Student Goals: She Wanted to Do It Herself
- Science Goals: The Real Thing
- Teaching Goals: Keeping Your Hands in Your Pockets
- Teaching Goals: At First I Was Hesitant
No Longer the Same

This vignette is from an observer’s notes of the fourth meeting of an all-girls club. There were approximately 17 girls in attendance, more seventh graders than sixth or eighth. They were doing a mouse dissection activity that the girls had requested.

After the students were all seated, the club leaders began to pass out materials. Each student received a dissection tray, rubber gloves, a mask, and a gauze cap. The students seemed excited and chattered nervously. Marlena, a Triad Scientist, went over the utensils in a small kit: scalpel, forceps, scissors, and pins “… to stick the mouse down to the tray.” Some girls responded with a characteristic, “E-yuu!” Next Chrysal, the other scientist club sponsor, began an explanation of how to cut. She explained that the diagram was of a rat and that a mouse was even smaller, so they would have to be very careful. She described how to feel for the diaphragm, sternum, and rib cage; how to make the first incision; and how to cut so as to see everything clearly. As Marlena began to place the body of a small white mouse in each girl’s tray, Chrystal said, “If you’re uncomfortable, spend some time with it first, feel it, move it around. No one has to do it … .”

There was a good deal of squeamishness at first, while each girl was waiting to get a mouse placed on her tray. But not long after, when they had their mice, the girls went to work, some asking for assistance pinning them to trays and exclaiming, “Everything’s so small!” One group of three girls worked together on a single mouse, but most worked on their own. The students earnestly settled into their task. There was a lot of conversation among themselves and with the scientists. They slowly, cautiously began dissection, breaking the sternum, making the first incision, removing fur. I eavesdropped on random comments:

“Help! Is this okay?”

“We’re inside!” “So am I. Is it bleeding?”
“It’s the ribs. You can’t cut that.”

“Okay, I think that’s as deep as I want to go right now…”

“That’s the large intestines, see?”

Students continually raised their hands. The noise level reduced as girls work even more intently. Some moments were spent working in silence; others were mixed with frequent outbursts: “Look! I got it!” and “This is cool!” As the work continued and the students acquired more information, their discussions and comments became more inquisitive:

“Is the green thing the intestine?”

“Where’s the stomach?” “See. It’s right here.”

“These are the kidneys.” “Do they have two? I can’t find the other one.”

“It looks like crabmeat.”

“Can I see what it ate?”

“I found poop too.”

“Oh my, it’s [the liver] big!”

“Can we open the tail?”

“What would happen if I cut the heart open?”

“I found a bone behind the heart.” Marlena suggested, “Why don’t you study the diagram. Does it say what it is? Is it the esophagus? The backbone?”

A group of three girls debated the sex of their mice.

It struck me that by the end of the activity these girls were no longer the same nervous and timid students who began this activity. They had become so comfortable that their energy began to swing to the opposite extreme. Not only were they exploring, some continued cutting, fearlessly separating their mouse in every conceivable fashion—removing eyes and tongue. One girl playfully held up her work calling out, “Look, genuine mouse coat.” I didn’t think any student was going to walk out of that room quite the same. I knew I wouldn’t. That was about as real as discovery can get.
CHAPTER 3: Student Goals

Reflection Questions

- What teaching strategies are the adults in this vignette using to encourage students to explore? What are they doing? What are they not doing?
- In your experience what kinds of science lessons are most successful in building students’ confidence to explore?
- Describe a time when you have noticed your own interactions with students encouraging their confidence to explore? limiting their confidence to explore?
- Consider the student statement, “Look, genuine mouse coat.” To what extent can a teacher discern and communicate the boundary between exploration in the service of learning and inappropriate use of materials? How might you decide when students’ explorations are no longer linked to learning? Is it truly possible for us to know?

Links

- Student Goals: The Real Microscope
- Student Goals: Safety Was a Concern
- Science Goals: Putting Sugar in Water
- Science Goals: The Real Thing
- Science Goals: A Daunting Task
- Teaching Goals: Talking in Questions
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