How does a federally funded, science-outreach project end up with changes in university teaching practice that it did not anticipate?

That was the situation we discovered at the conclusion of the Geneticist Educator Network of Alliances (GENA) project at the American Society of Human Genetics (ASHG). This 3-year project, funded by the National Science Foundation (NSF), called for establishing a national network of geneticist–teacher partnerships that would work together developing learning plans for high school students and implementing them in high school classrooms. The content of the learning plans was organized around students’ common misconceptions about genetics and based on concepts represented in the teachers’ state science standards.

The GENA project had three goals:

• help geneticists and high school science teachers form mutually beneficial partnerships around the development of inquiry-based educational materials that address standards and misconceptions in genetics;

• provide an infrastructure that supports geneticists’ engagement in meaningful education outreach in their schools and communities as a worthwhile professional activity; and

• harness the resources of ASHG— as a professional society—to promote the value of K–12 educational outreach in colleges and universities.

The first goal was directly related to calls from advisory boards and funding agencies to improve secondary STEM education via greater outreach by university faculty, which manifested itself, in part, in the Math-Science Partnership program at NSF. At the same time, research conducted as part of the Change and Sustainability in STEM Higher Education (CASHE) project indicated that faculty who were engaged in formal outreach programs were often discouraged from committing significant time because their efforts were viewed by university administrators as distractions from their primary work as researchers (Shapiro et al., 2006). The second goal derived from the findings of CASHE as a potential solution to the problem of faculty outreach being unappreciated in universities, with obvious drawbacks to such outreach as an enhancer of secondary STEM education. And the third goal essentially tested the hypothesis that scientific professional societies, which function in many ways as arbiters of quality (e.g., through their journals and meetings), might be able to leverage their influence to help support university/K–12 outreach. Those goals were achieved, to greater or lesser extent, which was satisfying but unsurprising given the structure of the project (Bourexis & Kaser, 2010). However, nowhere was there a goal of motivating geneticists to improve their own teaching skills, but that’s exactly what transpired. So how did this happen?
Project description

After a participant-selection process, the GENA project established partnerships between geneticists and teachers that were characterized by direct interactions, rapport, and a sense of personal responsibility to the partner. Both teachers and geneticists completed applications as part of the selection process. Partnership building began with a 3-day summer institute where scientists and teachers started the process of developing lesson plans that used misconceptions as the content framework and inquiry as the pedagogical framework around which content of interest to both partners would be taught. Inquiry was chosen because it has been shown to be effective in increasing conceptual understanding (Minner, Levy, & Century, 2010; Shymansky, Kyle, & Alport, 1983).

To help the geneticists understand “inquiry” in the instructional sense, the institute exploited their more familiar experience of inquiry—the discovery process by which new knowledge is generated—and built from there. Recognizing that scientific investigations begin with questions, project staff—during the course of the institute—were able to demonstrate how Socratic teaching is a simple instructional manifestation of this concept. Further along a continuum of inquiry, guided inquiry was defined as the model that partnerships should strive for when designing lesson plans. It is practical and consistent with secondary science teaching (the target for the lesson plans), and many of the teacher partners had experience using it already. Guided inquiry is more advanced than merely asking students a question before didactically presenting an answer (a not-unfamiliar practice in undergraduate lectures), but it is less sophisticated, complex, and difficult to implement than full and open investigations initiated by students, which are at the far end of the inquiry continuum. Full and open inquiry was deemed impractical for the project’s purposes and has been found to be relatively ineffective (Kirschner, Sweller, & Clark, 2006). The project did not rigorously apply a precise guided-inquiry framework but rather chose to emphasize more familiar, accessible, and practical examples of guided-inquiry instruction—for example, BSCS materials structured around the 5E learning cycle, which was used during the institute and applied by teams when developing their lesson plans.

Misconceptions were selected as the genetics content organizer, on the basis of a pilot workshop that indicated geneticists were generally unaware of this pedagogical concept and found it engaging and powerful. (The high school teachers, by contrast, were generally familiar with the concept, which was unsurprising given their formal training in learning theory and pedagogy.) Also, ASHG was in the process of conducting its own research on genetics misconceptions and chose to draw on examples from that work. Specifically, ASHG analyzed essays produced by high school students as part of its annual DNA Day Essay Contest and identified problems in a number of areas, such as patterns of inheritance, genetic determinism, and the genetic basis of disease (Shaw, Van Horner, Zhang, & Boughman, 2008). Faculty/teacher teams analyzed some of these student essays during the institute to see how alternative and/or incorrect conceptions manifested themselves in students’ thinking, and teams were required to target their lesson plans to address one or more specific misconceptions. As noted by Tanner and Allen (2005), misconceptions are not only a powerful way to formatively assess students’ current understanding and to effect conceptual change, they also can inform the development of summative tools that exploit prevalent misconceptions and push students to deeper understanding. Workshop sessions at the institute included topics such as how students learn, common misconceptions in genetics, formative and summative assessment, resources for teaching genetics, and state science standards related to genetics. Scientists and teachers also had opportunities to learn about the differences between secondary and postsecondary institutions and the best ways to communicate after the workshop.

Lesson plan development required that each team account for the realities of K–12 systems in an era of high-stakes testing. In other words, lessons had to address applicable state science standards, assessment requirements, and pedagogies that help students build a solid and coherent understanding of essential concepts.

After the institute, the partners completed their planning and implemented their lesson(s) together in the high school classrooms over the course of the following academic year. Between July 2007 and 2009, a total of 70 partnerships conducted their lessons.

Evaluation methods

ASHG engaged The Study Group Inc. (TSG) as its GENA external evaluation partner. A senior TSG evaluation team collected evaluation data between April 2008 and September 2010 following a sequential mixed-method evaluation design where data collected through one method were used to elaborate, corroborate, or expand on findings from data collected through another method (Creswell, 2003). In this study, the sources of evidence included documentary, survey, and interview data-collection techniques.

TSG distributed an electronic survey to all Cohorts I, II, and III geneticists near the end of the GENA experience (N = 70), asking them about the effectiveness of their partnerships, their understanding of teaching genetics at the high school level, their skills in identifying and providing appropriate instruction to counter students’ misconceptions, their level
of confidence after participating in an educational outreach experience, and their repertoire of pedagogical approaches. Response rates were 100% for Cohort I participants, 89% for Cohort II participants, and 95% for Cohort III participants.

TSG also interviewed each Cohort I geneticist (from the pilot 2007 cohort; N = 13) to elaborate on intentions expressed by the cohort in the initial survey and to identify plausible longer term benefits of GENA participation. In 2010 TSG distributed an electronic survey to all Cohorts I and II geneticists who had completed their GENA experience at least one year prior to the survey administration. This survey solicited geneticists’ reports on the current status of their original GENA partnerships, dealing with students’ misconceptions about genetics, changes in their own teaching, participation in professional development on the teaching of genetics, and participation in education outreach activities. The response rate was 89%. Finally, TSG developed profiles of five scientists whose survey and interview responses indicated substantial long-term career impact from their GENA experience (see http://ashg.org/education/gena_scientists.shtml).

The evaluation followed valid and generally accepted data analysis procedures. Survey data were analyzed using various measures of central tendency (i.e., descriptive statistics). Documentary data were catalogued and sorted by evaluation question; interview data were content analyzed and linked to the documentary and survey data. Finally, data across sources and methods were integrated to develop the findings for each evaluation question (White, 2005). This article specifically addresses the findings related to the impact of the GENA experience on scientists’ teaching practice.

Limitations of the evaluation

TSG believes that the findings presented here are a valid presentation of GENA’s impact on geneticists’ teaching practice. However, the evaluation questions are descriptive and interpretive. The findings are limited to logical and reasonable associations between geneticists’ experiences and influence on their knowledge, understanding, commitments, and practice. Much of our evidence is self-reported viewpoints of geneticists, and we are well aware of a possible discrepancy between what faculty members say they do and what they actually do in the classroom (Ebert-May et al., 2011). We believe that our sequential mixed-method evaluation design strengthens the validity of the findings and minimizes self-report respondent bias. We also based an evaluation “finding” only on the responses of the majority of geneticists, in another effort to control for respondent bias. Nonetheless, the findings are not generalizable to other ASHG or NSF projects, although there may be lessons learned or insights that merit consideration when others are designing or undertaking similar projects in the future.

Results

The GENA experience had a substantial impact on the understandings and skills of participating geneticists in many areas of professional practice, including their own teaching (see Table 1). Even allowing for differences in the impact pattern across cohorts, programmatic impacts (i.e., those reported by a majority of geneticists) included the following:

- adapting instruction to communicate genetics to diverse audiences,
- becoming more skillful in identifying and providing appropriate instruction to counter students’ misconceptions,
- using inquiry-based instruction,
- broadening their pedagogical repertoire, and
- developing assessments of student learning.

As we continued to follow the Cohorts I and II geneticists for 1 and 2 years after their GENA experience, we found that the majority of geneticists reported that the changes they made in their own teaching practices were still in place (i.e., were sustained). One year or more after their direct involvement in GENA, these geneticists were working hard to incorporate elements of inquiry-based instruction into their teaching practice. Many were investigating alternatives to a straight lecture approach by introducing group work sessions, projects, and more class discussion. About half of the geneticists reported also experimenting with designing instruction around a learning cycle or with different types of assessment activities.

Here are comments that characterize some of the changes geneticists reported making in their own teaching practices:

- I totally changed the way I teach meiosis to college freshman as a result of my GENA partnership.
- I have made changes to my lectures and classroom exercises and also to my assessment tools (exams).
- I use questions in a more constructive way . . . and let students do more of the investigation. I take a more “research” approach to lab experiences in genetics class.
- By being introduced to the concept of a learning cycle, I feel that I have been able to improve the structure and design of my lectures.
- I’ve been getting the students more involved in inquiry-based learning instead of just standing there lecturing them. That’s not always popular with the students — some of them prefer just to sit there and listen.

The words of the participants best convey the impact that the experience had on them. One teacher

Unexpected Outcomes
and researcher from Maryland was surprised by how much she learned about teaching. “There were instructional strategies that I had never seen before,” she explained. Now she is starting to incorporate strategies into her own teaching. She reported wanting to “get across why the knowledge matters, not just what the facts are.” Now she focuses on what students need to know rather than what her research field would dictate as new or most important.

Going into the classroom after years of research, a Pennsylvania scientist specializing in craniofacial genetics reported her greatest gain was confidence in teaching. “The GENA program helped break the ice,” she said. Equipped with her newly acquired pedagogical practices (including using a conceptual “hook,” mixing instructional styles, using pre- and posttests), and encouraged by her positive experience, she now feels more self-assured.

Yet another genetics professor from Pennsylvania decided to participate in GENA “because I thought I might learn something, but that it probably wouldn’t last,” he said. By learning ways to keep his students engaged and actively involved, he reported “receiving more benefits for my teaching than I ever expected.”

Although none of these comments and reported changes demonstrates transformation of higher education lectures into student-centered learning environments, they do suggest that faculty recognized deficiencies in their previous practices and were struggling to incorporate more features of inquiry and student-centered instruction into their classes.

**Discussion**

So why did GENA influence scientists’ own teaching practices? We included items regarding the geneticists’ teaching practices in our survey and interview evaluation activities as part of the universe of possible outcomes, and not because changes in geneticists’ own teaching practices were a priority goal of the GENA project. Yet this appeared to be a pervasive result of the partnerships geneticists formed with high school teachers and their engagement in a yearlong educational outreach program. In hindsight, we wondered why geneticists’ GENA experience influenced their own teaching practices. We suggest three possibilities: insights and skills gained through their GENA experience, the emphasis on misconceptions, and the indirect instruction.

**Insights and skills gained through their GENA experience**

GENA geneticists had multiple opportunities to learn where gaps might exist in their understanding of how students learn and multiple opportunities to help rectify those deficiencies. For instance, 80% of the geneticists introduced to the ASHG and other genetics websites through the GENA workshops reported consulting these resources for lesson planning. Forty percent had sought out more professional development in the teaching of genetics. In addition, the scientists had an experience designing and delivering novel genetics instruction to high school students, and that instruction was far more student centered than the didactic lectures more familiar to university science faculty. That experience may have been of sufficient impact that the scientists were able to transfer it to their own teaching.

**Emphasis on misconceptions**

The importance of addressing misconceptions in genetics was part of GENAs’s foundation. It was stressed in the GENA workshops, and it was at the core of the learning plans that partners developed for the high school students. The concept of misconceptions was new to most of the scientists even though the subject area is rife with such misconceptions. For example, many students believe that all mutations are harmful, which is not accurate. This misconception can interfere with students’ processing of higher concepts related to genetic variation, such as the idea that much of the variation in genomes is neutral and thus not under selective pressure.

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**TABLE 1**

<table>
<thead>
<tr>
<th>Teaching practice</th>
<th>Number (%) of Cohorts I &amp; II geneticists who reported a change</th>
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<tbody>
<tr>
<td>Adapting instruction to communicate genetics to diverse audiences</td>
<td>32 (80%)</td>
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<tr>
<td>Addressing students’ misconceptions</td>
<td>31 (78%)</td>
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<tr>
<td>Using inquiry-based instruction</td>
<td>30 (75%)</td>
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<tr>
<td>Using different pedagogical approaches</td>
<td>26 (65%)</td>
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<tr>
<td>Developing assessments of student learning</td>
<td>22 (55%)</td>
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<tr>
<td>Aligning subject matter with a set of content standards</td>
<td>16 (40%)</td>
</tr>
<tr>
<td>Developing lessons plans around a learning cycle</td>
<td>13 (33%)</td>
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As a result of GENA’s emphasis on misconceptions, 78% of the Cohorts I and II geneticists raised their awareness of misconceptions and their impact on understanding, and almost all of the geneticists described an action they took to address these misconceptions. Most often, these were actions embedded in the geneticists’ own teaching. For example, consider the following comments from three geneticists:

- I have become a better teacher. I have learned to identify misconceptions and build upon them to teach… complex concepts.
- I address the misconceptions more directly and more clearly. I make an effort to debunk misconceptions and oversimplifications from years of previous instruction. GENA has also made me keen to other areas of student learning that may lead to misconceptions.
- In the past I probably would have tried to deal with the “symptoms” of a misconception (e.g., the “wrong” answer) whereas now I look for a possible misconception as the root cause of a wrong answer and try to deal with the misconception.

**Indirect instruction**

Assuming there is some truth in the stereotype that the higher the grade level taught, the more the teacher focuses on content over pedagogy, GENA took an indirect approach to changing behavior. Rather than addressing pedagogy directly, it provided an experience that put the scientists in a different role. And changing a person’s role is often an effective way of changing their behavior (Biddle, 1986).

**Conclusion**

Lest the reader marvel at our foresight, be assured that improved teaching by the geneticists was not planned beforehand—at least not consciously. Determining outcomes and selecting activities to achieve those outcomes is a very complex process. It is easy to either underestimate or overestimate the impact of a set of activities. In our case, we probably underestimated. The GENA project’s primary activities were apparently sufficient to impact the geneticists’ teaching even though that was not a target outcome. The cumulative effects of the GENA workshop, along with the planning, implementation, and assessment of the lesson plan in the teacher’s classroom, did transfer to the scientists’ own classroom teaching. Future attempts to improve undergraduate faculty instruction might consider the potentially powerful role that carefully structured K–12 outreach may play. Also, it is worth noting that there is no reason to assume that the outcomes achieved here would be unique to geneticists.

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**References**


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