ACHIEVING SCIENCE SOL WITH A HANDS-ON APPROACH

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Sweet Briar College is a small, highly selective, four-year liberal arts college, located in the foothills of central Virginia. As a women's college, Sweet Briar has always felt very strongly that it belongs at the forefront of education for women in *all* fields, but especially those, such as the sciences, which have been traditionally viewed as male domains. Sweet Briar's science faculty believes that the best way for students to *learn* science is for them to *do* science. To support the mission of providing Sweet Briar students with a laboratory-rich science education, the College has invested, over the last decade, significant resources and has been successful at attracting notable outside support for facilities, equipment, and research. The impact of these efforts has been striking: since 1992, enrollments in science courses at Sweet Briar have increased by 42%, while the percentage of degrees awarded in the sciences has increased by 75%. Of our entering students, 36% now list science as their first academic interest, compared to just 18% of freshmen women nationally [1]; and, 35% of Sweet Briar students now graduate with science degrees, compared to just 16% of women graduates nationally [2].

In our project, "Achieving Science SOL with a Hands-On Approach," we wanted to use Sweet Briar's strong science program and the newly developed materials from the Women in Chemistry Consortium (WCC) to make a local impact in our region of central Virginia. Through making summer research internships available for local high school students, Sweet Briar science faculty began a dialogue with area science teachers. In conversations with area teachers over the following months, Sweet Briar science faculty members realized the need for creating better connections between the College's resources and the area school systems. The Department of Chemistry at Sweet Briar College has had an on-going interest in K-12 science education, witnessed by its strong participation in the WCC, as well as its leadership role in a follow-on project, *New Pathways to Chemistry*. These projects were multi-college collaborations, funded by the National Science Foundation, the Dreyfus Foundation, and the duPont Foundation, to create materials for use first in college and later, in high school chemistry courses. Our project would take these materials and implement them in the area school systems.

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Our project serves teachers in the central Virginia area, including public and private schools in the city of Lynchburg and six surrounding counties; these systems are within the immediate area of Sweet Briar College. Our summer workshops are held in the Guion Science Center at Sweet Briar. On-campus housing in the College dorms was provided to teachers who requested it. Large group discussions over lunch were held in the College cafeteria.

The *New Pathways to Chemistry* laboratory modules, the basis for this project, were specifically designed to be effective for all types of students, especially girls, young women, and minorities. These students may not have had opportunities for curricular or extra-curricular use of scientific equipment and might, therefore, feel less comfortable with a traditional science laboratory exercise [3]. When students are uneasy with the process, they are much more likely to feel alienated and to be "turned off." By using materials that are familiar to the students, and by asking questions that are relevant to real life, the modules attempt to minimize the effects of prior experiences or lack thereof. The open-ended nature of the modules is also extremely valuable for encouraging women and minorities to view themselves as scientists. The active involvement of the student in the design of the experiment, in the determination of which observations to make, and in the making and interpreting of those observations, makes the student a practitioner of science—in other words, a scientist. The student succeeds at doing science and, is therefore more likely to try more science, since nothing builds self-confidence like success.

Our project's goals are founded on the previous work of colleagues involved in the WCC. Their goals, like ours, are to "extend to high school teachers the inquiry-based chemistry laboratory curriculum which has been successful attracting and retaining young women in chemistry and to establish a collegial environment for college professors and high school teachers to learn from each other." Additionally, we saw the opportunity to attract talented middle school teachers into the program in order to begin to draw the attention of their students, impressionable young people, toward science. We were especially interested in reaching girls and minorities who traditionally do not see themselves as scientists. By participating in this project, area middle school teachers were provided a stimulating work environment in which to modify the high school chemistry experiments to best meet their own physical science Standards of Learning.

This project contains three essential parts: an intensive laboratory course for pre-service undergraduates; a two-week intensive, collegial laboratory experience for in-service teachers;

and, a follow-up program which encourages and supports the in-class use of the laboratory approach. This serves to help pre-service teachers see modules in action, and aids the in-service teachers by providing needed assistance during lab time. Our objectives are to:

- Increase opportunities for central Virginia's school children to utilize inquiry based, hands-on learning in areas of scientific inquiry and experimentation, thus enabling them to learn more about modern science and its methods, and exciting them about scientific investigation.
- Positively affect teacher attitudes toward doing experimentation in the classroom.
- Increase the amount of time teachers spend doing experimentation with children in the classroom.
- Provide the teachers with a curriculum that supports their classroom content using an inquiry-based, hands-on approach.
- Positively affect pre-service teacher attitudes toward science education.
- Create a network of science teachers in the region and link science teachers with resources at the College.

In the summer of 1999, we conducted two, two-week workshops. The first workshop was conducted for a group of seven undergraduate students from three central Virginia colleges. The second workshop was conducted for 26 in-service teachers from our local area. The lab experiments that we used were part of the *New Pathways to Chemistry* curriculum. The same experiments were done in the in-service teacher workshop as were done in the pre-service teacher workshop. Our workshops began each day with a brief introduction on the subject. Lectures and whole group instruction were kept to an absolute minimum. The college faculty instructors modeled their teaching to encourage the teacher participants to learn and experience the new material in a hands-on way. Participants were engaged in intense morning laboratory exercises. The experiments that were taught were based on real-world applications of chemistry and were usually multi-session lab modules. In the two-week session, the participants completed twenty of the *New Pathways* modules, or variations thereof.

The workshop lunch hour consisted of small and large group discussions. Topics were chosen to complement the subjects of the morning exercises. A set of open-ended questions was posed at each lunch table and the participants seated at the table used the questions to guide discussion. After lunch, the whole group would meet to talk about what was learned and discussed. Subjects for lunch discussion included: safety, instrumentation, science out of the

classroom, and building partnerships. Notes from the small group discussions were taken at each lunch table and are available on our web site.

The afternoon hours of the workshops were less structured. Teachers were given a variety of resources including computers, lab equipment, chemicals, and facilities for small group meetings, in addition to the full attention of the college faculty and teaching assistants. Teachers were encouraged to continue lab work, testing new ideas, modifications or extensions of the morning experiments. Teachers from the same school or school district were also encouraged to meet together in small groups to talk about curriculum planning and implementation. We also encouraged the teachers to use our computer labs, including word processing and internet access, to create materials based on their morning lab experiences for student use.

Our project offered participants two additional types of support. Materials and supplies were offered to the teachers to give them the requisite resources they needed for successfully implementing the experiments in their classrooms. Teachers primarily purchased lab supplies, such as beakers, hot plates, test tubes, pipettes, dropper bottles, wash bottles, storage bottles, petri dishes, graduated cylinders, and the like. Additional funds from the Gwathmey trust provided us with a set of sixteen Educator Spectrophotometers. These instruments were used in the summer workshops to introduce the teachers to modern scientific instrumentation. Approximately one and a half days of the workshop involved the use of the spectrophotometer. During the academic year, the instruments were out on loan according to a rotating schedule of the teachers' design. The course instructors and the teachers worked together to move the instruments around the region to the various schools throughout the school year. All 26 of the teachers signed up at the end of the workshop to have the spectrophotometers brought into their classrooms during the upcoming academic year—some teachers requested all sixteen spectrophotometers at the same time!

During the academic year of 1999-2000, teacher participants were involved in implementing the experiments in their classrooms. Three of the pre-service teachers assisted in implementation for at least part of the academic year. One of the pre-service teachers completed 120 hours of classroom visitation.

In an end-of-workshop questionnaire, teachers responded with comments such as:

> "I feel more like a scientist and have gained [an] understanding of how to help students link their science experiences in school to outside the classroom and other subject areas to increase student interest and motivation."

> "I have had the opportunity to become more confident using equipment such as the spectrophotometer..."

To the evaluation statements, teachers were asked to respond using a 5-point scale: 5= strongly agree, 4=agree, 3=neutral, 2=disagree, 1=strongly disagree. All 26 teacher-participants responded with "5-strongly agree" to the following two evaluation statements: "I would consider taking another summer workshop from these instructors" and, "I would recommend these instructors/this program to other teachers in my school."

We are still receiving data from the teachers regarding the extent to which they were able to incorporate the experiments into their classes. Brian Caldwell reports that he worked with the new chemistry teacher at Buckingham County High School implementing three of the course modules. Brian stated, "The information and activities were useful. We had a new chemistry teacher; he found the activities a great help in planning course content." Marilyn Buck, in the fall semester, asked her tenth-grade chemistry students to write us a note regarding three of the experiments they tried that semester. Katie Kirkwood reported, "[The spectrophotometer lab] helped me understand the ideas of transmittance and absorbance more clearly. It was easier to see the differences than it was to understand it by reading it out of a textbook."

On the same evaluation, teachers were asked to respond to this statement: "I intend to do more hands-on science activities in the classroom than I have done before, increasing the amount of time my students have for inquiry-based learning"; the response was an average of 4.4 on the 5-point scale.

Free-form comments from the teachers include: "I really hope additional workshops for physical science eighth - sixth can be developed"; "Before I came here, I *had only a few* experiments to do with my students and now I feel that I can do at least one a week"; "I would

be interested in seeing more programs like this especially in the upper-elementary sciences. I would be interested in participating in such a workshop."

The interim report from the College and University Resource Institute (CURI) evaluators was also very encouraging to us regarding the impact of the project. Their conclusions were drawn from a site visit during the July workshop and a review of all of the pre- and post-workshop questionnaires. In this report, the evaluators state, "These responses [with respect to the principal outcome of the project] should assure the staff that the program was successful." With respect to the pre-service workshop in particular, the evaluators stated that, "primarily, [the workshop] changed the participants' attitudes and made them more positive toward science." It seemed to the evaluators that we were also successful in meeting our goal of creating more connections between the local schools and the College. The evaluators stated that, "... high ranking [to a set of four questions regarding setting and planning] responses indicate a real strength in the program in the areas of instructor skills and partnerships with the participants; ... This adds a permanent dimension to the project whether or not more funding is acquired."

In our end-of-workshop discussions with the participating teachers, we noted the strong opinion among these participants that more needed to be done in terms of "covering more SOL." There was an especially strong indication that interest in continuing education in science was highest among the lower grade teachers (in this group fourth through sixth grades). We acted on this recommendation in designing our 2000-2001 SCHEV-Eisenhower Professional Development Workshop—an extension of the 1999-2000 project—into the fourth - eighth grades. In our 2000-2001 Eisenhower program, we are including experiments in chemistry (based on the WCC modules, adapted for the lower grades), biology, and physics.

One of our 1999-2000 teacher participants was a special education teacher. Most of the participating teachers have mixed-ability classrooms. While the hands-on nature of the science experiments is a learning strategy that works well with children who need special education, we did not address this issue in our workshop. We, and our outside evaluators, consider that this is an area of science education that could be addressed more specifically in a future program.

The federally funded Dwight D. Eisenhower Professional Development Program (Eisenhower), through the State Council of Higher Education for Virginia (SCHEV), supported our project. We received an Eisenhower grant in the amount of $50,417 to fund our project. In addition, we received an award of $12,000 from the Gwathmey Memorial Trust that provided

our teachers with sixteen spectrophotometers, used for the summer workshops and taken into the classrooms during the 1999-2000 school year. The project cost was $1,527 per participant, excluding the Gwathmey funds.

Teacher participants received a $500 stipend for their completion of the two-week summer workshop. No additional compensation was given for their academic year efforts. Teachers also received a $400 budget for the purchase of supplies needed to carry out the implementation of the experiments in their classrooms.

The in-service teachers also received continuing education credits from Sweet Briar College. Pre-service undergraduates received a $300 stipend for completing the two-week workshop. They were also eligible to receive undergraduate credits (as internship credits) for participating in the academic year implementation aspect of the project.

The request to SCHEV was made in November of 1998 for our Eisenhower grant. Collaborating faculty in chemistry and biology designed the project (Jill Granger and Robin Davies); the grant was written with input from Sweet Briar's Department of Education (Jim Alouf) and the College's Director of Foundations and Government Grants (Tom Loftus). Project planning began in September of 1998 with meetings of the Sweet Briar project team and representatives from the area high school departments of science and administration.

In addition to face-to-face meetings with the area teachers and administrators, we also mailed our proposed workshop curriculum to area middle school teachers to seek their opinion on the appropriateness and applicability of the experiments to the science content taught in grades seven and eight. By adapting the high school level chemistry experiments to also meet the Standards of Learning for the middle school course in physical science, we were able to serve more teachers in our area.

In the initial stage of the project, we had no budget for paying the pre-service student participants a stipend: we envisioned that the students would sign up for "free" education, tuition-waived. When, after months of heavy recruiting, we had no pre-service participants enrolled, we surveyed the education students at Sweet Briar. We learned that they had a need to make money during the summer to meet their academic year expenses. Based on this information, we re-designed the budget to provide the student participants with free on-campus room and board (partially paid for by the grant and heavily subsidized by the College) and a

modest stipend. Once we could cover the out-of-pocket expenses for the students, we began a second advertising campaign on the three college campuses.

In-service teachers were genuinely grateful for the $500 stipend they received for the workshop. They were absolutely thrilled to receive the additional materials and supplies for academic year implementation. This level of support has given us a generally high level of teacher cooperation for the entire project. Teacher participants are also very concerned with earning recertification points for their participation from their school systems. This issue has been a complicated one for us to deal with because of the number of different participating schools. We have taken to providing the teachers with a certificate of completion and assigning them one continuing education credit (CEU) for each hour in the workshop. Thus the two-week workshop, which met from 9:00 to 3:00 each day, had 60 CEUs attached to it. Assigning this type of credit was a new venture for this traditional liberal arts college; it required us to work with the President's Office and the Registrar to get the policy and paperwork in place. By giving continuing education credits across the board, the individual school systems can interpret the teacher's participation to best fit their local recertification guidelines. Typically, the teachers received six out of nine points needed (or sixty out of ninety points needed) for recertification. For teachers who do not have a master's degree, it was important for us to note on their certification that the workshop was a science content course in order for them to get recertification credit for science content.

SCHEV, CURI, and the Sweet Briar College project team evaluated the project. SCHEV sent a site visitor to the workshop for one day. This visitor interviewed participants and mingled in the labs observing the teachers' activities. She also sat in on our lunchtime discussion forum. Two outside evaluators were employed by the budget of the project. These evaluators were hired because of their experience evaluating such projects. The CURI evaluators made a one-day visit to the workshop. They also conducted a pre- and post-workshop survey of the teachers regarding their attitudes toward making changes in their classrooms and their views of education reform. The SBC project team administered their own pre- and post-workshop questionnaires to the undergraduate group and to the in-service group assessing multiple aspects of the project from the specific (rating each individual experiment) to the general (rating the overall quality of the experience). In all, the teachers responded to over fifty questions. All of the information obtained by the SBC faculty was forwarded to the CURI evaluators to be included in their summative report. At the end of the workshop, teachers were also given a short form for reporting on activities conducted during the academic year.

At the end of the academic year June 2000, teachers were mailed a final project questionnaire written by the SBC faculty. They were asked to return it along with their academic year activity reports. Approximately half of them have been returned. These will also be forwarded to the CURI evaluators for inclusion in their summative report.

We imagine that the basic structure of this project could be adopted for almost any situation. Key elements include a dedicated faculty team with expertise in the content area and patience for the managerial issues that arise, a supportive institution to both host and support the program, and a willingness on the part of area schools to make the project known to their teachers. ■

References

[1] *The American Freshman: National Norms for Fall 1997*, The American Council on Education and the University Of California at Los Angeles Higher Education Research Institute.

[2] *Science and Engineering Degrees: 1966-94*, NSF 96-321, National Science Foundation, Arlington, VA, 1996.

[3] S.V. Rosser, "Female Friendly Science: Including Women in Curricular Content and Pedagogy in Science," *The Journal of General Education,* **42** (1993) 191-220.

INTERVIEW WITH JILL GRANGER

Q: What career path did you follow to reach your present position? Is this what you originally aimed for, or were there twists that brought you here?

A: I went to Butler University, in Indianapolis (near my hometown) and got my Bachelor's degree in chemistry. During the summer before my senior year, my senior undergraduate year, and the summer following graduation, (fifteen months in all) I worked as a co-op student at Merrell-Dow Pharmaceuticals. I was doing research on potential anti-viral compounds in search of a drug to arrest the action of the enzyme reverse transcriptase. I had also done undergraduate research at Butler in previous years at the Holcomb Research Center (an independent lab on campus). In addition, I had worked with several faculty members in the chemistry department and the College of Pharmacy doing research projects. I liked doing these research projects and enjoyed working with the scientists. My dad encouraged me to get the co-op position at Dow—which turned out to be the primary reason I considered going to graduate school.

I went to graduate school primarily to do anti-cancer research—specifically in the area of "rational drug design." I had considered that much of what I had done at Dow was fairly irrational (get a panel of drugs, test them all, look for trends, find similar compounds, test again...). I wanted to get a better understanding of drug action and structure relationships. To a lesser extent, I wanted to go to graduate school to gain the credentials that I would need to write a textbook (writing has always been one of my interests) for high school chemistry. I went to Purdue, slightly to the north.

I did cancer research at Purdue and was a National Institutes of Health (NIH) Cancer Center Fellow. My research involved a variety of techniques including manual and robotic synthesis, high field NMR, and molecular modeling and computational chemistry. I also received a scholarship called the GE-Purdue Foundation Teaching Incentive Award to help support me as a graduate student and encourage me to consider a teaching career. At the end of my stay (1988 -1993) at Purdue, I realized that teaching has always been my real passion and interest—I had done most of the requirements for teacher licensure while I was at Butler—and so I sought a faculty position. I was lucky enough to get hired at Sweet Briar (and had an offer at another college as well). (Maybe someday I'll get around to doing that post-doc.)

Q: Have you been involved in similar programs before? Was there a particular moment or stimulus that caused you to begin this project?

A: I've never been involved in a teacher education program before. I would say that my interest in the project was stimulated by a National Science Foundation (NSF) speaker that I heard at the 1998 Council on Undergraduate Research meeting in Los Angeles. He was basically reporting on NSF's statement "Shaping the Future" and spoke passionately about "cradle to grave" education. It was very inspiring. I also went to a workshop at that conference on Juniata College's Chemistry Van project. I could see a lot of similarities between the area of Pennsylvania that Juniata serves and this part of central Virginia. I was really fired up by the idea of a college serving as a resource to area schools and their teachers. When I got back to Sweet Briar College, my colleagues were very supportive of me moving my research efforts in this direction. I guess having four kids of my own (now ages 0.5, 4, 6, and 8) - keeps me energized about teacher education. I am also a member of Project Kaleidoscope's Faculty of the Future, a group of college faculty leaders. This organization also encourages personal growth and professional development. They are a great supporter of college/school partnerships and faculty involvement in change and reform.

Q: Have there been any unique or unexpected consequences for you resulting from your project?

A: The first thing that comes to mind is the Virginia Math and Science Coalition (VMSC) award. That was quite unexpected! I guess the amount of publicity we have received in general has been unexpected—certainly we've gotten more press-time on this project in the year and half we've been doing it than I got in all of the eleven years I was doing cancer research! In general, that's the great thing about working with the teachers and the schools. People in the schools are really grateful for everything you do for them—no matter how small an effort it may be—and you get instant feedback. It's a great feeling to know that what you're doing is making a difference to people. Not to say that cancer research doesn't make a difference to people's lives but... you just don't get the same kind of feedback in the same time frame.

Q: Are you able to identify the greatest lesson you have learned and the rewards you have gained through working on "Achieving Science SOL?" What is the greatest benefit you see coming to students—and teachers—through their engagement with this project?

A: With respect to personal rewards - see Question #3. The greatest benefit I see is that we get to bring teachers together to work on improving science education and we get to allay a lot of their fears in that regard. It still surprises me how anxious many of the teachers are about "teaching science." When we bring them together, they gain a lot of strength from their peers, who may be less anxious, and the environment and resources that we are able to provide.