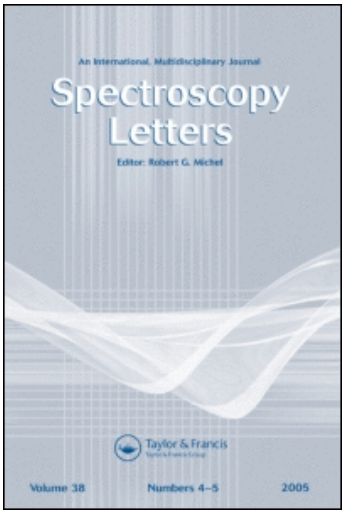

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Introducing Spectrophotometry in Grades 6-12 Using a College-Based Spectrophotometer Loan Program

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Introducing Spectrophotometry in Grades 6–12 Using a College-Based Spectrophotometer Loan Program

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ABSTRACT

Science faculty members at Sweet Briar College have joined in partnership with area schools in a novel project bringing spectrophotometry to teachers and their students in grades 6–12. A sourcebook of classroom experiments has been created and field-tested. These experiments are written around "real-world" themes and problem solving scenarios and invoke an inquiry-based (constructivist) approach to teaching and learning. The broad-based theme that has emerged is "Light, Color, and Energy" which we tie into Virginia's Standards of Learning (SOLs) for each of the science classes that are involved. The College maintains and distributes a set of 21 Spectonic® Educator™ spectrophotometers that are used for summer professional development workshops for teachers and are loaned to trained teachers during the academic

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year. The 6th–12th grade classroom spectrophotometry experiences are also used in the education of future teachers, as project components are included in the College's pre-service education courses. Undergraduate science students, interested in careers in education, have also contributed to the project in the development and testing of new classroom experiments. Funding for this project includes both external and internals funds, including an initial $42,000 investment from the Camille and Henry Dreyfus Foundation's Special Grant Program in the Chemical Sciences (New York, NY) and the Richard and Caroline T. Gwathmey Trust (Richmond, VA).

Key Words: Spectrophotometry; Standards of learning; Spectrometer loan program; Grades 6–12.

BACKGROUND

In 1999 we were concerned about the lack of hands-on, investigative types of instruction in our area schools, including a near complete absence of student exposure to real scientific instrumentation. Although the national education agenda[1–3] and the, then, newly instituted Virginia Standards of Learning (SOLs) were calling for more inquiry-based instruction, we perceived that in our area, this call was not being heeded. While there were a variety of legitimate reasons for this situation, we felt that there were at least three barriers that we, as practicing scientists, could address: lack of teacher education and training in inquiry-based instruction, lack of student access to scientific equipment, and lack of appropriate classroom materials suitable for the grade 6–12 audience that involved the spectrophotometer in real-world types of investigations.

In the summer of 1999, the Richard and Caroline T. Gwathmey Trust (Richmond, VA) provided Sweet Briar College with a $12,000 grant to be used for the acquisition of spectrophotometers in support of a regional teacher education initiative in science. Using these funds, we were able to purchase a set of 16 Spectronic® Educator™ spectrophotometers, which were used for a summer teacher training workshop and which were then taken by the teacher participants back to their school districts for student use during the academic year. The summer teacher education workshop was funded by the State Council of Higher Education for Virginia (SCHEV) through the federal Dwight D. Eisenhower Professional Development Program. This science education initiative began a partnership between the Sweet Briar College science faculty and area teachers which continues to grow and flourish.

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Our project was designed to provide a vehicle for both in-service teacher development and pre-service teacher education in science. The educational content was developed as an extension of a laboratory program initially developed by a group of college faculty, The Women in Chemistry Consortium, supported by the National Science Foundation and the Jessie Ball duPont Fund.[4] The Women in Chemistry Consortium[5] was interested in making the college laboratory a more inquiry-based, real world environment. The idea for our project was to use this college-level laboratory program as a model for a focused project that would take SOL content in grade 6–12 science courses and teach these subjects using an inquiry-based pedagogy with a single instrument, the spectrophotometer. This instrument was chosen because of its omni-presence in both college-level and real-world laboratory settings and because of its applicability to a wide variety of science topics. Our request for these instruments was in direct support of both teacher-training and in-class implementation.

As we began planning for the first summer workshop, we came to realize that new curricular materials would be needed to support the use of the spectrophotometers in 6th–12th grade classrooms. The curricular materials that were available were not appropriate for our intended audience and were not directly applicable to teaching the SOLs. We obtained a 2-year $30,000 grant (award number SG-00-126) from the Camille and Henry Dreyfus Foundation's Special Grant Program in the Chemical Sciences (New York, NY). This award supported a consortial program for science teacher education and the development and testing of a series of inquiry-based laboratory modules for use in science courses in grades 6–12, utilizing the spectrophotometers provided to us by the Gwathmey Trust. It was our goal to instill in the participants, and subsequently their students, a greater appreciation for the importance of chemistry in everyday life; while at the same time, being cognizant of the need to stay within the structural guidelines of the State mandated learning objectives. Thus the conceptual framework of the project is built around appropriate themes and science concepts that are emphasized in the Virginia SOLs in science and also include math and technology skill areas as well.

Since 1999, we have written a source book of 14 experiments (totaling over 200 pages) for use in grade 6–12 classrooms using the spectrophotometer in a variety of age-appropriate, real-world contexts that support the SOLs in the various science courses at these grade levels. We have conducted four intensive teacher education workshops, where the teachers were taught to use the spectrophotometer to solve problems, trained to use the instruments in a variety of contexts, and shown how to perform routine maintenance. During these workshops new experiments were tested and evaluated by the teacher participants. The trained teachers now take the spectrophotometers on loan into their classrooms for student use and conduct on-site teacher

training of other teachers at their schools during the academic year. The Sweet Briar faculty make limited trips to schools to observe and participate in the use of the spectrophotometers in the classrooms. Evaluation of the project is conducted through pre- and post-workshop questionnaires, through surveys of classroom activities, and interviews. A website (utilizing the Blackboard® campus computer technology) is used to support the community created among the participants in the project which enables the teachers and faculty to share information about specific laboratory modules and equipment sharing.

Currently the project is funded by a second grant from the Gwathmey Trust which has provided us with an additional five Spectronic® Educator™ spectrophotometers, a 2003 summer teacher professional development workshop, resources for carrying out an extensive evaluation of the in-class use of the laboratory experiments, a 2004 project conference, and an on-campus science enrichment program for girls in grades 6–12.

ACTIVITIES

The Curriculum

Each new experiment written for the project has two parts: a student guide and a teacher guide. Undergraduate science students, interested in future careers in education, have been involved in the research and testing of potential experiments for inclusion in the project. In the student guides, a brief but pertinent background and introduction is provided, followed by preparation instructions, laboratory procedure, sample calculations (if needed), and reporting instructions. The process of scientific writing and data collection is emphasized in the student guides. Students are instructed to create data tables, graphs, and to write out conclusions and answers to delivered questions. Student guides are written at a grade-appropriate level and with student interests keenly considered.

In the teacher guide, there is an extensive background section for each module. Also included are a materials and equipment list, directions for making needed solutions, lab set up instructions, information on special precautions (if needed), and resources for additional information. We highlight "Target Topics" to demonstrate how each module supports achievement of specific student learning goals from the Virginia SOLs. Each of the teacher's guides also has an extensive data analysis section, including sample data. Teacher guides are about 7–10 pages in length each, student guides are around 5 pages each; thus the workbook (all experiments developed to date) is now about 200 pages total. Experiment titles and very brief descriptions are given in Table 1.

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Table 1. Spectrophotometry based experiments developed for grade 6–12 classrooms.

Title	Target audience	Description
Superman has X-ray Vision, How Sensitive are Your Eyes?	6th grade, general science	Introduction to the concept of light as a type of energy. Students use the spectrophotometer to answer: which is more sensitive to color the instrument or the human eye?
The Rainbow Connection	6th grade, general science	Students discover the relationship between color and wavelength. They observe absorption and transmission and relate their observations to color. Experiments allow the student to discover properties of light and color for him/herself.
The pH Balanced Cabbage	7th grade, life science	Students determine the lambda max for a set of pH standards. Later they use the method they have just developed to determine the pH of a variety of products.
The Mystery of Maple Red Revealed	7th grade, life science	Students extract pigments from plant materials they choose themselves, then create an absorbance spectrum. They learn how the extraction process can influence their results.[6]
Species Survival: Save the Rare, Endangered Shoefish	7th grade, life science	Futuristic scenario asks students to use the spectrophotometer to determine nitrate concentration as an assessment of water quality and make recommendations on habitat quality.
A Totally Organic Experience	7th grade, life science	Students use plants as the starting point for executing an inquiry of their own design on the topics of energy and life processes, photosynthesis.[7] Students take an active role in the real-world nature of the experience.

(*continued*)

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Table 1. Continued.

Title	Target audience	Description
YUCK! There's Beet Juice in My Kool Aid!?	8th grade, physical science	Students investigate the relationship between absorbance and concentration as they determine the amount of beet juice in Kool-Aid® Blastin' Berry Cherry Mega Mountain Twists.
Read the Fine Print on that Label	8th grade, physical science	Students pose two types of questions: which FD&C food dye(s) are in the product? and How much of the food dye is in the product? Results and conclusions can be compared to product labels.
In Our Search for Whiter and Brighter, How are We Affecting Our Water?	9th grade, earth science	Students use Virginia's Chesapeake Bay watershed as a case study of human influence on water quality. They use the spectrophotometer to determine phosphorus in detergent and wastewater samples.[8]
Heme for Your Health: Checking for Anemia	10th grade, biology	Determination of hemoglobin concentration in animal plasma is made. Students explore the role of heme in life functions, and the structure/function relationship of the hemoglobin as it carries its oxygen.[9,10]
Spit Happens	10th grade, biology	Students create a calibration curve for thiocyanate using iron(III) nitrate as the complexing agent. They then test their own saliva for thiocyanate concentration. Class results are shared.[11,12]
The Snack Bar Solution	11th grade, chemistry	Based on their experiences as youngsters inventing Kool-Aid® concoctions, the experiment lets them decompose the drink mixtures based on physical characteristics.

(*continued*)

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Table 1. Continued.

Title	Target audience	Description
Drug Action, Drug Delivery	11th grade, chemistry	Students will be provided with compounds of varying polarity in order to study the partitioning of the substance. Students will determine the partition coefficient for their compound based on its relative concentration in the polar and non-polar layers.[13]
Party Chemistry 101	11th grade, chemistry	Students use the spectrophotometer to correlate absorbance with the length of the piece of crepe paper (as dye extracted in solvent). Later students are asked to make a determination about a two-component system.[14]
Magic and Mirrors	11th grade, physics	Students use a simple colored food dye solution to do a comparison of performance characteristics of two spectrophotometers. Detailed schematics of the instruments are provided, as well as tools necessary for allowing students to understand the mechanical nature of the analytical instrument.

Teacher Education Programs

The purpose of the summer teacher workshops in this project is two-fold: to provide an avenue for testing of our newly developed lab modules, and second to provide locally trained teachers in this area of chemistry (spectrophotometry and its applications). Subsequent to their training during the summer session, the teachers use the lab modules in their schools and provide us with feedback on implementation. In the two Dreyfus-sponsored summer teacher training workshops in 2000 and 2001, we focused exclusively on the use of the spectrophotometer and on developing our new lab activities for the middle school and high school setting. In 2003, we hosted a group of new teachers to the project along with a group of returning teachers in a 3-day workshop sponsored by Gwathmey Trust. The new participants

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received a crash course in the function and application of the spectrophotometers and learned to carry out five of the project experiments. The returning participants held group discussions about spectroscopy related concepts and were divided into smaller groups to work on experiments that they chose from among the project activities. This allowed returning teachers to focus on particular experiments and to try new ones. We also held a panel discussion where teachers, experienced with the instruments in their classrooms, answered questions from the whole group. These questions related primarily to classroom management, and scheduling.

The Spectrophotometer Loan Program

Currently we have a set of 21 Spectronic® Educator™ spectrophotometers to loan to the participating teachers. Teachers contact the Sweet Briar College Department of Chemistry's Laboratory Supervisor, and arrange for pick up and/or delivery of the instruments. The Laboratory Supervisor checks the instruments and maintains them in good working order and keeps an updated loan schedule on the project website. This level of project staffing has been provided by the College and requires, on average, approximately 2 h per week of the Laboratory Supervisor's time during the academic year. Typically the teachers take the instruments out on loan for a period of 1–2 weeks. During that time, the teachers involve their students in a variety of experiments drawn from the source book we have written. Some of the teachers utilize the instruments only once per year, others once per semester, and still others multiple times per term. We also have teachers who use the instruments for summer enrichment activities with their students. In addition to the spectrophotometers, the loans also include a set of glass cuvettes, and a cuvette rack with each instrument. Teachers may also borrow electronic balances (we have five for loan), volumetric flasks (we have 24 100 mL flasks for loan), 10 and 100 mL graduated cylinders, a boxed grating set (Education Absorption Spectra Kit, manufactured by ThermoSpectronic®) used for the overhead projector, electromagnetic spectrum posters, and/or an instrument manual on request to support the classroom activities as needed.

RESULTS

Teachers have been very excited about the experiments we have developed for use in the 6th–12th grade classrooms. In our summer workshop evaluations, and in presentations we have given at teacher conferences in Virginia, we have found that the teachers' comments are universally

positive; they look forward to sharing their new knowledge with their peers, and are enthusiastic about using the spectrophotometers during the academic year.

Since 1999, we have trained 43 middle school and high school teachers, representing 10 different school systems, in the use of the spectrophotometer. We have developed 14 classroom experiments (a 200 page sourcebook) that utilize the spectrophotometer to teach appropriate science, math, and technology concepts and skills at the 6th–12th grade level. Consequently we have established a strong network of collaboration and communication between the area schools and the College. We estimate is that since the inception of the project, these instruments have spent at least 2 weeks per month in the various teachers' classrooms and have been used by over 5000 students.

We believe that this project has the potential to make a profound impact on the culture and learning environment experienced by the students of teachers who have become invested in this project. Results from pre- and post-workshop surveys (1999–2003) demonstrate that, based on their workshop experiences, the participating teachers:

- Intend to make changes in classroom instruction.
- Intend to introduce new and/or updated content into their courses.
- Demonstrate marked improvement in knowledge and skills in content areas and processes related to the use of the spectrophotometer in problem-based situations.
- Feel that the project has enabled the College and their schools to begin a mutually beneficial partnership.
- Recommend this program to other teachers.
- Demonstrate a more positive attitude toward doing hands-on science activities in the classroom.
- Believe that use of these experiments in the classroom will excite students about scientific investigation.

Free form comments from the workshop surveys included these:

> With the activities provided by this program I am ready to change my curriculum to a more inquiry based hands-on learning environment. I feel that my knowledge in the physical science content area has also increased through participating in this program.
>
> This workshop has given me background knowledge, specific experiments to use, and a greater appreciation for the inquiry approach to learning. It has given me some confidence in my abilities to use this approach as well as materials to use.

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In addition to evaluating the summer workshop experiences, we have also evaluated the in-class implementation of the laboratory activities and use of the spectrophotometers. To gather information we asked teachers to complete a very short questionnaire about classroom activities, and learning outcomes. These surveys were called for throughout the academic year and were returned by mail, e-mail, and through the program web site. However, the return of information was very sparse overall. We combined this survey information with individual interviews, and we held dinner conferences in 2000 and 2002. We found that the dinner conference was the best way of getting information about how well the experiments are working in the classrooms. Teachers' suggestions and critiques can then be used to make improvements in the materials.

The information that we obtained from 1999–2002 about the in-class use of the spectrophotometers demonstrate positive effects of the project on classroom learning and improvements in moving classroom instruction towards a more hands-on inquiry-based approach. Positive effects were seen both in students' cognitive abilities as well as improvement in attitude and interest. Teachers found that the experiments were content rich and were easily incorporated into SOL learning objectives. Teachers were very well pleased at how well use of the instruments could be tailored to specific students' learning needs. Typically they saw improvements at both the high and low end of the spectrum. An added effect was that the teachers also noted behavioral improvement among the students. One middle school teacher said, "Students behave more maturely trying to show that they are worthy of using the instruments. These activities bring out the best in students." For the 2003–2004 school year, we will be videotaping and conducting interviews with students and teachers as the instruments are used. This information we hope will allow us to document specific positive effects on learning brought about through the use of this hands-on curriculum.

Our work, initiated with the spectrophotometers in 1999, has spawned other science-education related projects at the College and has drawn the science faculty into new collaborations. Notably we have received a 2001–2003 award from the National Science Foundation's Course, Curriculum, and Laboratory Improvement program for the support of a project entitled "A Standards-Driven, Inquiry-Based Science Curriculum for Future Elementary School Teachers," which was funded in full at $50,446 (NSF Award #0126968). Through this project we have instituted three new science courses required of all our pre-service elementary school teachers. (This is a doubling in the number of preparative courses in science required of these future teachers and is coupled with additional new required courses in mathematics.) These new science courses, collectively known as the "Science by Inquiry" courses, are based on hands-on, professionally relevant experiences

for the future elementary school teacher, using an inquiry-approach. Each course is constructed as a combined lecture-lab and has a significant component of inquiry-based pedagogy. The use of the spectrophotometers is included as part of this new undergraduate curriculum. Other related projects include continued funding for elementary school focused teacher education workshops on hands-on learning in math and science.

CONCLUSIONS

Our collaborative endeavor began with a summer workshop in the use of a hands-on science laboratory curriculum followed by a spectrophotometer loan program that extended into all of the local school systems, including the public high schools and middle schools in a seven county area, as well as several private schools. The project has been the catalyst for a variety of additional teacher education projects in math and science and has helped us obtain new funding for these important projects, including three additional awards from the SCHEV Eisenhower Program, a 2003 award from the SCHEV directed federal No Child Left Behind Title IIA act, and a 3-year award from the National Science Foundation CCLI Program supporting the development of a new series of "Science by Inquiry" courses suited to the needs of pre-service elementary school teachers. This support has been used for the development of a teacher-supported, inquiry-based curriculum and an extensive K-12 and college collaboration.

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