Biology Experience IMPACTS CAREER DEVELOPMENT

MARY JANE MOORE   WILLIAM R. HOLMES

Since the late 1950s when the United States responded to the Soviet space initiative with science education reforms, society has struggled to meet the needs of the workplace by preparing students with the prerequisite skills for the practical application of science and technology. More recently, with the release of the report, *A Nation at Risk* (National Commission on Excellence in Education, 1983), concern over technological advances by Japan and other industrial nations (Yager, 2000) spurred new interest in science reform, eventually resulting in the release of the *National Science Education Standards* (National Research Council, 1996).

MARY JANE MOORE is a graduate student and WILLIAM R. HOLMES, Ph.D., is Associate Professor of Counseling and Development, both at Lamar University, Beaumont, TX 77710; e-mail: holmeswr@hal.lamar.edu.

In general, the *Standards* represent a consensus concerning needed improvements in science education related to scientific literacy, in particular, the use of scientific information in the workplace as well as everyday situations.

The goals of the reform effort are familiar to most science educators: science for all persons, teaching for understanding and application of processes, adopting a broader approach to curriculum and an integrated approach to the improvement of science education (Raizen, 1998). In addition to classroom teachers, science achievement and systemic change are focal points in a wide range of related areas such as policymaking, subject matter specialization, and assessment (Lee & Seoung-hey, 2000), as well as in industry, where there is concern about the future of scientific innovation and advancement.

Integral to the reform process is "the premise that science is an active process" (NRC, 1996). Unfortunately, it is often assumed that involvement in "hands-on" activities will ensure an understanding of the nature of science (Bybee, Ferrini-Mundy & Loucks-Horsley, 1997). This is not necessarily the case. Students must not only participate in activities that are "hands-on," but activities and laboratory experiences must be inquiry-based, requiring students to be mentally engaged in the processes of reasoning and thinking (Gallagher, 2000; Huber & Moore, 2001; Moreno, 1999). In addition, a contributing factor for success in achieving systemic change is the development of supporting relationships (St. John & Pratt, 1997). Such relationships include those formed with local universities and the scientific community.

Much has been written suggesting that mentoring experiences, wherein a partnership is formed between the student and an adult, can do much to support academic gains. Mentors frequently help students think productively about career possibilities (Casey & Shore, 2000), and in situations where there is professional respect, mentors may serve to encourage and guide students in the development and achievement of goals. However, few models exist combining inquiry-based, authentic science, and mentoring experiences.

Although the reform effort sets forth the goal of science for all, educators are aware that the "one size fits all" approach may not be entirely appropriate. In considering the best approach for meeting the needs of high achieving or gifted students, success is often achieved where the general education system is constructed with elasticity, so that students may find a match between potentials and curricula, leading to insight and creativity (Sytsma, 2001). High achieving and gifted students thrive in an environment where the parameters of learning extend beyond the confines of the classroom.

This study evaluates a program instituted in 1991 for high achieving biology students at Port Neches – Groves High School, Texas, in which students participated in genetics research under the guidance and supervision of a United States Department of Agriculture geneticist, Dr. Shannon R. M. Pinson. Students worked in the classroom at school and the laboratory at the Agricultural Experimental Station as well as in the field, gathering and analyzing data as part of three successive research projects from 1991 through 1996. The study reviews the impact of their participation on their college and career choices as well as their understanding of science methodology, genetics, agricultural science, and product development.

Project Model

From an educational perspective, the collaborative research project was initially intended to provide students with an authentic research experience, allowing them to participate in science experimentation in which the outcomes were unknown. Specifically, the intent of the teacher was to provide a practical application experience enhancing the genetics content taught in the classroom. This "doing" approach to science supports the science reforms and allows for a shoulder-to-shoulder collaborative teaming of science professionals, students, and teachers. Such an approach may be the best to achieve scientific literacy (Duchovnay & Joyce, 2000).

From a research perspective, genetics studies require the accumulation of large amounts of data. Involving students in the data collection process allowed for more replications in a shorter amount of time. Consequently, both parties in the collaborative project had something to gain by the partnership. The teacher had the opportunity to involve students in authentic research and the scientist had the advantage of additional labor. Three separate groups of students participated in two separate research studies investigating: (1) the determination of the number of aroma genes and their allelic relationships in six aromatic rice lines and (2) the inheritance of seedling vigor and cold tolerance of rice varieties.

In order to facilitate the organization of participating students and meet the requirements of school class scheduling, a cooperative approach was implemented, designating two to four students per class as "experts" who worked most closely with Dr. Pinson. These expert students went to the Texas A & M University Agricultural Experimental Station after school and on Saturdays for a period of eight weeks to research, harvest, and prepare seeds as well as to conduct studies to perfect the research and data gathering methods to be used by the other students in the classroom setting. Selection of students as experts was determined primarily by scheduling requirements. Students needed to be available some afternoons and Saturdays to work with Dr. Pinson.

Since Dr. Pinson was unfamiliar with the workings of the high school classroom and the abilities of sophomore students, and the teacher was unknowledgeable about rice farming and harvesting, the students were valued for their expertise in both settings. Also, the expert students were responsible for instructing their classmates on the background and procedure for data collecting, as well as ensuring that errors in collection were minimized.

From the educational perspective, such a collaborative project allows for several specific advantages over the traditional laboratory model. Traditionally, students perform "experiments" in laboratory science classes that are not actually experimental, but rather are teacher-guided demonstrations of previously determined principles. In a research project such as the one implemented in Port Neches, the outcomes are not yet known, and the research itself is of importance to plant breeding programs and, eventually, to Texas rice farmers, the local economy, and the quality of food on the dinner table. Also, the teacher prepares most classroom lab activities, excluding students in the planning and preparation process. With this model, expert students were responsible for the design implemented in the classroom and helped Dr. Pinson, who served as mentor, to prepare the protocol for data collection.

This approach addresses the science reforms acknowledgment that most science "courses and student activities in the past have been unrelated to the daily lives of students" (Yager, 2000). Context is as important as the content or concepts and processes studied.

Also, because data gathering and analysis in the industrial setting often involve the use of technology, students were required to input data for Dr. Pinson according to her requirements using industrial software applications. In 1991, computers were not commonly used in the classroom setting. It was not feasible to record data by hand and then input the data later because recording it twice (once on paper and then transferring it to the computer) increased the chance for errors in recording data. Consequently, a local computer company was approached and agreed to provide, on loan, four laptop computers for data entry and analysis purposes. This was an important component of the model in that the science reforms also emphasize a collaborative approach, including others in the partnership and ownership of the science studied and learned (Yager, 2000).

Another incentive from the agricultural research perspective has to do with the recruitment of students to that field of study. There is a shortage of U.S. college students in science and particularly in agricultural science. Such projects may lead more young people to pursue scientific careers. Whether or not the experience impacts students' career paths, hopefully this exposure to real agricultural research will impact how each of them views agricultural products in their groceries and on their plates. "Food doesn't just appear. It is grown by farmers after scientists have spent years and years developing the product" (S. R. M. Pinson, Personal Communication, May 2, 1995).

Originally, the aspect of mentoring was not planned or considered. However, Dr. Pinson's role with students served to develop a partnership that portrayed a mentoring relationship, referring to the concept of mentoring as a learning partnership between individuals wherein "the mentor, typically an adult, acts as a guide, role model, teacher, and friend to a less experienced and often younger protégé" (Runions & Smith, 1985b as cited in Casey & Shore, 2000). Additionally research indicates that mentors provide support in helping students think productively about career choices (Casey & Shore, 2000).

Finally, the model included the built-in incentive of publication. Expert students were told that when Dr. Pinson published her findings they would be acknowledged in print by name for their assistance with her research. With the first group of students (1991), the publication draft was available just prior to their graduation from high school, enabling them to take tangible advantage of their participation.

Method of Evaluation

Since the project's inception in 1991, a total of 14 students have participated at the "expert" level and over 130 students have participated in the gathering of data in the classroom setting. Expert students were grouped by participation dates for purposes of evaluation, since the length of the individual genetics research studies and topics varied. Four students served as experts in 1991-1992, four in 1993-1995, and six in 1994-1996. Expert students have all graduated from high school and are at various stages of career development.

It was determined that it would be appropriate to evaluate outcomes of the expert group of 14 students by questionnaire, focusing on college and career choices, understanding of science methodology, agricultural science, and product development. Students were electronically mailed survey questionnaires and responded by e-mail. Questionnaires were verified as received by 11 of the 14 students. Eight of those 11 responded to the survey. Students were asked whether or not they had attended or were attending college and where, designated field of study or major, as well as whether or not they were attending or intended to pursue a graduate degree, where, and in what field. Students were also asked to respond to the following related to their participation in the research project:

- Compare and contrast this project with the types of class projects you ordinarily conducted.
- Did this project affect your career or college course choices? If so, how?

- Did this project affect you in any other way and if so, how?
- Did the experience help your ability to understand or appreciate the usefulness of genetics?
- Did the project change your thoughts and attitudes about any of the following?

  General Science

  Agricultural Science

  Product Development
- What did you like and dislike most about the project?

Students were also given the opportunity to make comments about any aspect of the research experience or evaluation. Each group of expert students was represented in the response sets: two from 1991-1992, three from 1993-1995, and three from 1994-1996.

Qualitative Summary of Data

All of the eight responding students were attending or had graduated from college. Seven completed or were completing undergraduate degrees in the sciences: three in the biomedical sciences, three in electrical engineering, and one in industrial technologies. The student not pursuing a science-related career was majoring in English. None of the eight was pursuing a career in agriculture, although two specifically referred to college choices related to genetics. Both worked in genetics labs on and off-campus. One plans to pursue a graduate degree in genetics.

All of the students referred to a deeper understanding of genetics and scientific methodology, and several specifically referred to the attention to detail necessary in science research that was introduced in the high school experience. Two of the engineering students suggested that emphasis on detailed study and the components of successful science processing work was beneficial to them in their current courses of study. One stated that an important decision for persons in the engineering sciences is whether or not to pursue a career primarily in the field, lab, or both and that the high school experience more than any other let him know that he preferred "a good mix of the lab and the field because it gives a better understanding of the events you are working on, or the problems to be solved."

With regard to agricultural science, four of the students admitted that they had no real idea what agricultural science was before the project. One stated that he previously thought it had something to do with "gardening." Another said that she originally thought it was primarily an "antiquated field" and was surprised to find it a "progressive field with many beneficial applications."

In response to what the students liked least about the project, all stated in some way that the work was tedious, time consuming, and most made mention of the mosquitoes and mud in the rice fields. Three qualified their responses by emphasizing the importance of understanding that research requires time commitment, tedious activities, and hard work in order to arrive at answers. They further recognized and noted the importance of attention to detail in science process thinking.

When asked about what they liked most, answers were consistent with regard to appreciation for the opportunity for involvement in authentic meaningful science. Several suggested that the experience was instrumental in enabling them to be accepted in other research programs. As one student stated, "I liked feeling like an actual scientist, with a definite purpose, without a guarantee that the research I was helping with would pan out or not." Or as another said, "I felt like what I was doing was going to be useful to someone else." Or still another, "The answer is unknown until you discover it. It showed how science is applied in real world projects."

Finally, several students referred to the development of leadership skills, teamwork, and "an overall desire to go above and beyond to succeed in any situation."

One stated that one of the things he liked most about the project was the opportunity students had to interact with one another and Dr. Pinson in an atmosphere outside the classroom. Still another said, "This project served to bring together six people in my high school class and really establish great friendships. Even when school became competitive, we never lost the relationships we had formed through the experiences at the lab." In addition, several mentioned Dr. Pinson in particular and noted her patience and thorough explanations. One specifically cited her ability to lay the foundations so well that students were confident to work independently in her absence. Still another said of her personal goals for college and career development, "I really feel that this early experience helped me receive acceptance in other research programs in college. This project really peaked my interest in the research sciences. I would most definitely have to admit that this project affected my planned career choice."

Conclusion

Although this study involved a small number of high achieving high school students, preliminary indications are that such an experience is one way to support science reform, and in turn, address the *National Science Education Standards*.

Selection of a career in the general sciences may be related to authentic science research, although participation may not encourage students to specifically select careers in a particular field of science. Participants did, however gain a better understanding of agricultural science and product development.

Authentic research experiences provide high achieving students the opportunity for inquiry-based application of science concepts that serve to enhance scientific literacy. In addition, forming collaborative relationships with science professionals positively affects the confidence of students and may also help them to set and achieve college admission and subsequent research goals.

References

Bybee, R., Ferrini-Mundy, J. & Loucks-Horsley, S. (1997). National standards and school science and mathematics. *School Science & Mathematics, 97*(6), 325.

Casey, K. & Shore, B. (2000). Mentors; contributions to gifted adolescents' affective, social and vocational development. *Roeper Review, 22*(4), 227.

Duchovnay, B. & Joyce, C. (2000). The spirit of discovery. *Science, 287*(5458), 1595-1597.

Gallagher, J. (2000). Teaching for understanding and application of science knowledge. *School Science & Mathematics, 100*(6), 310.

Huber, R. & Moore, C. (2001). A model for extending hands-on science to be inquiry based. *School Science & Mathematics, 101*(1), 32.

Moreno, N. (1999). K-12 science education reform–a primer for students. *Bioscience, 49*(7), 569.

Lee, O. & Seoung-hey, P. (2000). Conceptions of science achievement in major reform documents. *School Science & Mathematics, 100*(1), 16.

National Commission on Excellence in Education. (1983). *A Nation at Risk*. [On-line]. Available: http://www.ed.gov/pubs/NatAtRisk/indes.html.

National Research Council (NRC). (1996). *National Science Education Standards*. Washington, DC: National Academy Press.

Pinson, S.R.M. (1995). Personal Communication.

Raizen, S. (1998). Standards for science education. *Teachers College Record, 100*(1), 66.

St. John, M. & Pratt, H. (1997). The factors that contribute to the 'best cases' of standards-based reform. *School Science & Mathematics, 97*(6), 316.

Sytsma, R. (2001). Changing states of matter: science, education, and giftedness in 21st century high schools. *Journal of Secondary Gifted Education, 11*(3), 181.

Yager, R. (2000). A vision for what science education should be like for the first 25 years of a new millennium. *School Science & Mathematics, 100*(6), 327.

Yager, R. (2000). The history and future of science education reform. *The Clearing House, 74*(1), 51-54.