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Elizabeth Wallace

Southwestern Oklahoma State University

Jon E. Pedersen

University of Nebraska-Lincoln, jpedersen2@unl.edu

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Evaluative Case Study of a Summer Academy Program

by

Elizabeth Wallace
Southwestern Oklahoma State University

and

Jon E. Pedersen
University of Oklahoma

Abstract

The demands for technological workers have prompted a national effort to encourage all sectors of the population to consider careers in mathematics and science (National Council of Teachers of Mathematics, NCTM, 1989; NSF, 1988; Task Force, 1989). Yet students are not electing to enroll in science in school. One possible solution to increase interest in science is through summer programs. The Summer Academy in Plant Biology and Transgenics hosted by the Western Oklahoma State College, the Samuel Roberts Noble Foundation and the Oklahoma State Regents for Higher Education, is an intervention program in science for talented students and, in particular minorities and girls. This program is informed by the current research, employs a reformed curriculum and involves students working alongside practicing scientists in a highly interactive science experience and appears to have many positive aspects that enable it to reach its goals.

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Southwestern Oklahoma
State University

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Introduction

Shortages in Scientists

Future demands for technological workers have prompted a national effort to encourage all sectors of the population to consider careers in mathematics and science (National Council of Teachers of Mathematics, NCTM, 1989; NSF, 1988; Task Force, 1989) and researchers have eyed factors that affect participation in STEM (science, technology, engineering, and mathematics) careers for years. Ethington and Wolfle (1988) identified the number of advanced mathematics and science courses taken in high school as the strongest direct influence on choice of an undergraduate major.

However, students are not electing to take science in school. The lack of engagement in science has been associated with low interest levels in science and negative attitudes developed quite early in life (Schibeci & Sorenson, 1983). Ideally, science educators hope that both males' and females' interests in science would be high and this high interest would translate into increased enrollment for science classes and hence influence students' choices for undergraduate majors. Nevertheless, differences do exist in the prevailing perceptions of science and scientists held by female and male

students. Understanding student's perceptions or stereotypes of science and scientists may assist in designing programs that aid students in developing more positive perceptions.

Students Perceptions of Science and Scientists

Student perceptions of scientists have been investigated for nearly 50 years now. Although perceptions have been measured in many ways, one unique and quite successful way to examine perceptions is through the use of student drawn images of scientists. Chambers (1983) who first used students own drawings as a way to further examine perceptions modified Goodenough's Draw-A-Man-Test (1926) and developed the original Draw-A-Scientist-Test (DAST). The intent of DAST is to provide information regarding children's perceptions of scientists through representational drawings. To determine the variation from stereotypical "norms", Finson, Beaver, and Crammond devised the Draw-A-Scientist-Test Checklist (DAST-C) in 1995 to consider alternative images and facilitate ease of assessment of the DAST. Used widely throughout the United States and the rest of the world, the DAST has proven to be a valid and reliable instrument that allows researchers to examine perceptions. For example, Ruben (2003) and Finson (2001) examined cultural differences in the DAST and found the stereotypical imagery student's hold typically reflects Western ideas even for students living in countries other than the United States.

Studies assessing students' images of scientists (Krause 1977; Chambers 1983; Schibeci & Sorenson 1983; Maoldomhnaigh, M.O. & Hunt, A., 1998; Fort & Varney 1989; Finson, K.D., Beaver, J.B., & Cramond, B.L., 1995) show that students have common stereotypical images and perceptions of scientists (male scientists working alone

in a laboratory, frizzy unkempt hair, lab coats). Chambers (1983) and Schibeci and Sorenson (1983) found that as disturbing as this is, there is evidence to suggest that as young children progress through successively higher grade levels images of scientists become more and more stereotypical and more difficult to change. It seems that students' perceptions (stereotypical images) of scientists are well developed by the fifth grade, even though most students have had few experiences with science and scientists.

Influence of Teachers on Perceptions

At issue then, is how do we change or alter these perceptions. Thomas, Pedersen and Finson (2001) show that preservice science teachers hold similar stereotypical views of science, scientists and teaching science as their students. Furthermore, Finson, Pedersen and Thomas (2004) recently showed that students of teachers who had a more didactic style of teaching (vs. inquiry type of teachers) were more likely to hold stereotypical views of science and scientists. It appears that there are multiple dimensions inherent in the development of these images that involves both students and their teachers. Given this information, it would seem fitting that knowing students' and teachers' perceptions of scientists, science and science teaching may be critically important if educators are to effectively and positively impact students through instruction.

Influences For Choosing STEM Studies

Given that students have come into classrooms with well established stereotypical perceptions and attitudes towards science and scientists, it is no surprise that few are selecting STEM fields of study as they enter post-secondary education. Furthermore, all indications are that far fewer women than men are enrolling in STEM related studies.

Kenschaft lists no less than 58 societal, educational, and family customs affecting the participation of women in mathematics, while Boswell (in Chapman, Brush, & Wilson, 1985) identifies three sets of factors: external barriers, such as overt sex discrimination; social pressures from parents and peers; and internal barriers, such as negative attitudes toward mathematics. Lantz (in Chapman, Brush & Wilson, 1985) group the factors by (1) cognitive beliefs (usefulness of mathematics to one's educational or career goals), (2) affect (confidence, anxiety, enjoyment), and (3) achievement (spatial ability, grades, test scores, problem-solving ability).

A key influence may be attributed to parental stereotyping of careers, which affects girls' perceptions of the usefulness of mathematics and science. Parents may have lower expectations for daughters than sons and attribute their daughter's success in math and science more to effort than ability (Eccles, in Chapman, Brush, & Wilson, 1985). In addition, some girls have shied away from math and science as counselors sometimes discourage girls from selecting advanced math or science courses because they believe that quantitative fields of study are male-oriented. O'Brien, Kopala, and Martinez-Pons (1999) linked self-efficacy in a certain academic discipline to the probability of an individual choosing that career, and Zeldin and Pajares (2000) reported similar findings for females. Hence, individuals who have negative perceptions of science or scientists are unlikely to pursue such courses of study and, subsequently, not enter a science/science-related career (Hammrich, 1997). Teachers' perceptions and beliefs can affect students' goals and perception of their own abilities and teacher encouragement has been shown to be a positive influence on females' mathematics participation. Yet, teachers tend to treat boys and girls differently, often to the detriment of girls' achievement (Fennema & Leder,

1990).

The avoidance by females of science, engineering, technology and mathematics majors (STEM) has only made worse the already critical shortage of science teachers, health professionals, and researchers throughout the world and United States. Even as more women are entering the workforce, few are opting for STEM majors in college, thus exacerbating the problem. The under representation of women in STEM related careers; long an issue of equity and justice, has serious economic implications as the United States faces a shortage of scientists, engineers, and mathematically trained workers. In 1986, women constituted 49 percent of the nation's workforce, but only 15 percent of employed scientists and engineers and 24 percent of mathematicians (need reference here). Predictions foretold that by the year 2000 the need for employees in quantitative fields would be 36 percent higher than in 1986; however, the traditional pool of white males, which supplies most scientists and engineers, would shrink to just 15 percent of the new entrants into the workforce (National Science Foundation, NSF, 1988). It is clear more needs to be done to address these issues. If we are to engage more students—especially females—in the pursuit of STEM related careers, interventions must be designed specifically to address the issues related to the decline of students taking math and science courses.

Oklahoma's Summer Academies Program: Encouraging Minorities and Females

In Oklahoma, the Oklahoma State Regents for Higher Education chose to address the problems associated with the lack of STEM majors in 1989 when the state legislature set aside funds to establish a state-supported school of science and mathematics in an urban area. At the same time and to provide an opportunity for enrichment in math and

science for rural students, the Summer Science Academies program was established. The Summer Science Academies are immersion type summer “camp” experiences dealing with STEM topics held at various colleges and universities throughout the state. Colleges and universities are invited to submit proposals to host and run summer academies, but competition for funding is keen.

Oklahoma’s summer academy programs are designed to feature inquiry classrooms and actual laboratory experiences to introduce students to the rigorous academic preparation required for these careers. The goal of the state academy program is to provide bright, talented young students with opportunities they cannot experience in their regular school classrooms and to spark student interest in pursuing a higher education in the sciences and related disciplines (STEM); thus addressing the shortage of career professionals in these areas.

Western Oklahoma Academy

The Academy at Western Oklahoma State College deals with the interdisciplinary topic of plant biology and transgenics and incorporates biological science, physical science and mathematics. The academy is available to students throughout the state of Oklahoma who are rising 8th and 9th graders. Selection is based on demonstrated interest and individual considerations that may attract targeted students. Once selected, students are treated as “scientists in training” and work alongside various science professionals doing hands-on inquiry experiments. Students experience cooperative learning in small groups as they complete a research project in which they investigate a modified plant and examine both the biological and social problems that may be associated with GMOs (genetically modified organisms). At the conclusion of their work, students are required

to make a research style poster and present their findings to their classmates.

Students in this program have the opportunity to work in college laboratories and use sophisticated equipment in their laboratory explorations as well as in the field.

Students also have the opportunity to visit a research facility, the Samuel Roberts Noble Foundation, and take a tour led by practicing scientists and see the state of the art laboratories and greenhouses.

The Summer Academy in Plant Biology and Transgenics has been funded continuously since 1994 and throughout the years has served hundreds of rising 8th and 9th grade students. Student competition is high and participants are selected using criteria such as science grades, subject interest, and teacher recommendations. Meeting the goal of addressing workforce shortage in STEM professions is critical to the summer academies program. Specifically, the program addresses issues of attitude, low interest, and stereotypical perceptions and “avoidance” of science and math.

The intent of this current project is to discern if the intervention program (summer academy) exhibits the key traits for successful programs, as defined and determined by current research. To assist in this quest, a thorough review of current research on programs characteristics that have been identified as increasing minority and female participation in STEM majors was completed. These characteristics were then compared to the academy’s current program to determine if the academy is in fact addressing the shortages in STEM professions. Throughout the United States, various research-prompted programs are in place to address and alleviate shortages of science professionals. Literature would indicate, and we would concur that there are three major areas to examine: 1) youth intervention programs, 2) national math and science education

reform efforts and 3) involvement of the professional STEM community in the K-12 educational system.

Youth Intervention Programs

Intervention programs, both preventive and remedial, can possibly increase participation in STEM-related careers. These programs include large federally funded projects such as Upward Bound and Gear Up (Gaining Early Awareness and Readiness for Undergraduate Programs) among others. Preventive strategies, stressing awareness of career opportunities, development of mathematical knowledge and skills, and the importance of continued enrollment in mathematics and science, can reach students, parents, teachers or counselors. Remedial intervention programs target students who did not pursue advanced math and science in high school. The most effective age for intervention activities is pre-adolescence, before negative attitudes appear since the number of students considering careers in technical fields increases very little after ninth grade (Berryman, in Oakes, 1990).

Davis and Humphreys (1985) list five categories of intervention programs: (1) short-term interventions, including one-day career conferences, workshops, science fairs, or speakers; (2) printed and audiovisual products and exhibits; (3) experiential learning, including internships and field placements; (4) long-term efforts involving courses and curricula, retraining programs, and support programs; and (5) teacher education programs, including in-service and summer institutes to modify teacher attitudes and increase their skills. Research on the participation of students in STEM has focused on the identification of variables influencing persistence, however, a systematic evaluation of the impact of intervention programs on these variables is less common (Oakes, 1990).

Research indicates that changes at the affective and achievement levels have more effect on enrollment than those aimed at cognitive beliefs. Cognitive intervention increases awareness but does not affect behavior (Lantz, in Chapman, Brush, and Wilson, 1985), whereas training for spatial ability, which appears to have an experiential base, has been especially effective (Linn and Hyde, 1989).

Long-range programs are found to be more effective in changing attitudes, as one-day events do not involve active participation and rarely address the reasons females do not take advanced courses (Lantz, in Chapman, Brush, and Wilson, 1985). Peers and older students are effective communicators to young girls, as are adult males supportive of females' interest in mathematical careers. Students sometimes have difficulty identifying with women conference speakers; however, exposure to women in scientific careers over longer periods of time, as teachers or through internships, does develop role models and results in positive attitude changes (Tsuji & Ziegler, 1990). Interventions aimed at students' parents, teachers and counselors are effective in changing attitudes (Oakes, 1990).

Instruction in creating gender-equitable classroom environments is an especially effective form of teacher education intervention. There is some support in the literature for sex-segregated classes in mathematics and science, but Fox and colleagues (in Chapman, Brush, and Wilson, 1985) think programs that maintain a "critical mass" of female students effectively encourage participation.

Instructional techniques that de-emphasize competitiveness are conducive to female achievement (Tsuji & Ziegler, 1990). Damarin (1990), takes this a step further and recommends curriculum intervention involving cooperative learning, hands-on

activities, and solution of personally defined problems.

It would seem that an ideal intervention program would last a week or more, showcase the students' abilities, and build self-efficacy. The program would also include experimentally based activities, feature hands-on cooperative learning opportunities, and allow students to observe and work with practicing scientists in and out of their workplaces. Finally, there should be a career exploration component stressing the importance of a strong math and science background in the high school years, and this should be offered to students prior to 9th grade.

Science Reform Efforts

The Third International Mathematics and Science Study (TIMSS) and Third International Mathematics and Science Study-Repeat (TIMSS-R) are a source of data on the mathematics and science achievement of students in the United States compared to students achievement in other countries. TIMSS, conducted in 1995, involved 42 countries at three grade levels and was the largest, most comprehensive and rigorous assessment of its kind ever undertaken. In 1999, TIMSS-R collected data in 38 countries at the eighth-grade level to provide information about change in the mathematics and science achievement of our students compared to those in other nations over the last four years (Martin et al., 2000). The United States and many European countries did not fare well. As consequence of these findings, the United States government, as well as governments in other countries have promoted and financed math and science education reform.

The reformed science curriculum has had many challenges and pitfalls, as does any new program. One major challenge is effective assessment of the impact that federally

funded initiatives have had on advancing science education reform. Assessment is a very important aspect of any program, and certainly necessary in order to justify the huge financial investments made through grant awards to researchers. There are new challenges, however, because assessing the reformed curriculum focuses on science processes rather than on memorization of scientific facts.

The major financier of large reform-minded collaborations in the United States is the National Science Foundation (NSF), and one large project was Collaborations for Excellence in Teacher Preparation (CTEP). From its inception, it has been difficult to demonstrate the effectiveness of collaborative reform. It is not surprising that a number of new assessment instruments have evolved from the CTEP program, since there were few, if any acknowledged appropriate instruments in existence. This difficulty in demonstrating the effectiveness of collaborative reform arises, in part, because of the difficulty in defining and measuring reform. Among additional programs, the Fund for the Improvement of Postsecondary Education (FIPSE) and the National Science Resources Center's (sponsored by the Smithsonian Institute and the National Academies)'s Leadership and Assistance in Science Education Reform (LASER) have made contributions to the mission of science education reform. New national and state science standards, which encourage non-traditional approaches such as constructivist and inquiry-led curriculums, are becoming more widespread.

Reform efforts have provided us with the data necessary for the development of effective intervention programs. These programs should focus on science processes rather than memorization scientific facts, employ non-traditional pedagogies to include inquiry and constructivist methods, and assist students in developing their own problem

solving strategies. The classroom characteristics, student performance on problem-solving tasks, and the nature of inter-departmental cooperation in teacher preparation institutions should all be apparent.

Involvement of the Professional STEM Community in K-12 Education

The new "No Child Left Behind Act of 2001," particularly Title II, Part B - Math & Science Partnerships, has components to ensure that highly qualified teachers teach students. Various professional organizations have become involved including the American Society for Mechanical Engineers (ASME) International. The ASME has worked to inform policy makers and stakeholders and have published a vast a number of options that state legislators and their personnel may wish to pursue to improve K-12 Science, Technology, Engineering, and Mathematics (STEM) education. It is important that the education community consider these recommendations.

Experts agree that one key to improving student performance is the recruitment, training, and retention of qualified teachers. Recent studies suggest that, in the U.S. alone, 2.2 million new teachers will be needed in the next decade; yet, statistics indicate that U.S. colleges of education will not produce nearly enough graduates with degrees in education to meet the expected demand (ASME Education and Workforce). Furthermore, it has been found that graduates with degrees in science, technology, engineering, and mathematics are unlikely to pursue teaching careers. The lure of higher salaries in the private sector is further depleting the supply of qualified K-12 science, technology, engineering, physics, and mathematics teachers, while the pursuit of reduced class sizes and other demographic factors increase the demand for more qualified teachers. A related concern is the number of teachers who are currently teaching out of their

respective fields of expertise. In 1998, 28 percent of seventh and eighth grade math teachers in the U.S. were not certified to teach that subject, and 27 percent of science teachers at those grade levels were not certified to teach science.

Policymakers can enhance the recruitment, training, and retention of qualified STEM teachers by creating programs that attract STEM teachers. Strategies may include scholarships, student loan forgiveness, bonuses and tax incentives, the facilitation of alternative certification and transition-to-teaching programs for engineers and other technical professionals and the creation of distance learning opportunities for K-12 STEM teachers and students. Other recommendations include increasing STEM coursework in pre-service/university teacher training, allowing for differential pay scales to help attract and retain qualified STEM educators, improving in-service professional development focusing on STEM curricula, instituting mentoring programs for STEM personnel in schools and applying knowledge of how students learn in teacher professional development programs.

ASME International and other organizations currently partner with non-profit organizations and educational entities [e.g. the Junior Engineering Technical Society (JETS), and the Boy and Girl Scouts and Boy Scouts] to further K-12 STEM learning.

Policymakers should support the development of partnerships among educational institutions, industry, and non-profit organizations that foster adopt-a-school programs, promote relevant corporate summer externships for teachers in K-12 STEM positions, address school infrastructure needs for STEM education, develop recognition awards for private sector K-12 STEM involvement and produce, evaluate, and disseminate the best practices in K-12 STEM programs. Other recommendations include increasing STEM

coursework in pre-service/university teacher training, allowing for differential pay scales to help attract and retain qualified STEM educators, improving in-service professional development focusing on STEM curricula, instituting mentoring programs for STEM personnel in schools and applying knowledge of how students learn in teacher professional development programs Other I ideas could include the creation of incentives for STEM professionals to work with teachers and students, creating and funding the publication and dissemination of materials for public outreach and parental education on the importance of a quality K-12 STEM education(ASME Education and Workforce).

Development of effective STEM curriculum and assessment tools must be based on high standards of achievement. Nationally recognized standards for science, technology, and mathematics exist and have been widely adopted by the many states. These standards extend well beyond requiring knowledge of fundamental STEM facts. They require curricula that cultivate creative- and critical-thinking skills and encourage interdisciplinary approaches to issues and problems.

To enhance student achievement in STEM coursework, policymakers and other stakeholders should strengthen and align standards with expectations of higher education and industry, resist the tendency to "roll/push back" standards when assessment results are less than satisfactory, promote and endorse private sector standard-setting projects.

Development of effective STEM curriculum and assessment tools must be based on high standards of achievement. Nationally recognized standards for science, technology, and mathematics exist and have been widely adopted by the many states. These standards extend well beyond requiring knowledge of fundamental STEM facts. They require curricula that cultivate creative- and critical-thinking skills and encourage

interdisciplinary approaches to issues and problems.

Remaining competitive in the global economy will require the cultivation of technological literacy, talent, and expertise across all sectors of society. Efforts should be made to attract greater participation of women and minorities into STEM fields of study and careers and it will take teamwork between educators and scientists/mathematicians in order to do that.

Efforts to promote private sector involvement in STEM education can be encouraged by linking stakeholders, such as interested nonprofit organizations, area businesses, and informal education facilities, with each other to combine resources and deliver best practices. Ways should be explored to encourage the private sector to assist with instruction in grades K-12, i.e. help teachers teach certain topics, volunteer in schools and fund tours. Specific ways Legislators can provide tax incentives to corporations who provide for use of facilities for teacher computer or technology training, or assisting with school computer or laboratory maintenance, provide tax incentives for the donation of computer hardware or laboratory equipment and expendables, foster learning opportunities and practical experience for teachers through externships at corporations and offer tax incentives for non-profits organizations that provide professional development to teachers and administrators.

These options are largely based on expert and practitioner recommendations as well as programs, which are either in place, proposed, or under development in various jurisdictions. Research confirms that a successful intervention program must involve a diverse scientific community working in formal and informal settings. These communities must be stakeholders in the endeavor. The program must have high

standards of excellence, and make use of interdisciplinary approaches to issues and problems.

Conclusion

The Summer Academy in Plant Biology and Transgenics appears to have many positive aspects that enable it to reach its goal (see Table 1).

Table 1
Comparisons of Research Based Programs and the Summer Academy

Source	Trait	Evidence in Summer Academy
Schibeci & Sorensen, Lantz Chambers, Ethington & Wolfe	Career Exploration Curricular Requirements	Yes
Lantz	Intervention Duration	Yes
NSF	Nontraditional Pedagogies	Yes
ASME	Students Working with Scientists	Yes
ASME	Scientific Community as Stakeholders	Yes
NSF	Strong Laboratory Component Problem Solving	Yes
Damarin	Hands-On	Yes
Berryman	Early Intervention	Yes
Linn & Hyde	Experiential	Yes
O'Brien, Kopala et al.	Self-Efficacy/Achievement	Yes

Western Oklahoma State College in Altus, Oklahoma has collaborated with a world-renowned Oklahoma-based private research institution, the Samuel Roberts Noble Foundation and the Oklahoma State Regents for Higher Education, to fund and deliver a summer academy intervention program in science for talented students and, in particular minorities and girls. This program is informed by the current research and employs a reformed curriculum and involves students working alongside practicing scientists in a highly interactive science experience. Further efforts to involve the Noble scientists in the direct or indirect (internet) teaching of students could improve the program quality.

Western's academy challenges students by using latest technological tools in investigations of math and science, by demonstrating the viability of a research career in the sciences to project participants by interacting with scientists. Students participate in STEM career exploration activities and realize the curricular requirements necessary for success in those majors. The academy illuminates the multidisciplinary aspect between natural and physical science, mathematics, and computer sciences, as the students engaged in diverse aspects of science and mathematics by presenting a research project. This academy program is presented at a time when students are susceptible to influences regarding their futures; participants are rising 8th and 9th graders with ages ranging from 12-15.

This academy makes science and congruent disciplines relevant to students and the world in which they live. Students completed and presented a research project to the group and were evaluated on the scientific merit of their projects. In addition, some students who have traditionally not been college bound are encouraged to develop a can-do attitude of self-confidence. Students participated in many collaborative activities in lab

and in the field and the academy provided an opportunity for students to participate without undue financial hardship on their families, as the summer academy was held at no cost to the students or their parents, and it provided a balanced palette of intellectual activities for the students. Although the focus was plant biology and transgenics, students engaged in many team-building exercises outside of class time. The academy provided a forum allowing students development of science foundation skills as program objectives were aligned with national and state math and science standards.

This academy shows many of the marks of an effective program. The quality of the students' projects is much higher than expected. One key to encouraging student performance, we have found, is to have a lot of "outside of class" assignments and activities. These students are traditionally high performers and if anything I feel they should be pushed more. They have high standards set for themselves and are highly motivated by praise and achievement. Success of the academy is obvious in praises of students, teachers and parents- and many siblings of former academy participants apply for the program. Long-term effects on students' success in STEM areas are being examined. The OSRHE maintains a database, which allows them to track individual students' performances. Data gathered includes high school graduation rates and GPA, college admission, major choices, college performance and graduation rates.

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About the authors...

Elizabeth Wallace is on faculty at Southwestern Oklahoma State University.

Jon E. Pedersen is Associate Dean of Graduate Studies and Research in the College of Education and faculty member in the Science Education Center at the at the University of Oklahoma.

