Evaluation of Teaching and Research Experiences Undertaken by Botany Majors at N.C. State University[1]

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Abstract

Many science departments require undergraduate students to complete either a teaching or research experience. We developed a survey instrument to measure outcomes of teaching and research experiences from the student perspective. Results in the Botany Department at North Carolina State University demonstrated that those doing research are involved mainly in data collection and analysis, whereas those who are teaching are mainly involved with hands-on laboratory instruction. Nearly all students rated their experiences as very good overall and would recommend them to other students. Several positive educational outcomes were rated especially high, including a greater appreciation for teaching/research, greater initiative towards pursuing a career, an increase in skills, and greater consideration for attending graduate school. Students found that the experiences were effective at building five "leadership skills" that included team-work, problem-solving, getting along with others, analytical skills, and time-management, and somewhat effective at developing four others which included writing, speaking, work ethic, and integrity. Students rated academic-related outcomes relatively low overall, suggesting that motivation to make better grades or to take different courses changed little as a result of research or teaching experiences.

Introduction

Experiential learning in the forms of teaching and research can be extremely rewarding for undergraduate students. These experiences allow students to put classroom knowledge into practice and explore potential career paths. Teaching and research settings frequently present rich opportunities to build leadership skills such as team-work, problem-solving, getting along with others, analytical skills, time-management, writing, speaking, work ethic, and integrity. Perhaps most importantly, both teaching and research pose significant, open-ended challenges to students that provide opportunities for high achievement and excellence.

An increased emphasis has been placed on experiential learning in recent years, resulting in a greater need for assessment. Funding agencies such as the National Aeronautics and Space Administration and the National Science Foundation have expanded student research opportunities (Service, 2002) and consider "integration of research and education" as one of four criteria for reviewing scientific research grants (NSF, 2004). Furthermore, a number of national organizations have recommended expansion and improvement of efforts to include undergraduates in college/university research (NSF, 1996; Boyer Commission, 1998; Howard Hughes Medical Institute, 2002). Similarly, the concept of student-assisted teaching has been strongly advocated (Miller et al., 2001), as most laboratory instruction at U.S. universities is performed by teaching assistants (Sundberg and Marshall, 1993).

Recently, there have been surveys of student researchers in chemistry and biology (Mabrouk and Peters, 2000), medicine (Solomon et al., 2003), and psychology (Landrum and Nelsen, 2002), as well as a national survey of mentors in plant biology (Coker and Davies, 2002) and an institutional survey of liberal arts colleges (Research Corporation, 2001). Also, student research projects in particular courses have been described (Chaplin et al., 1998; McLean, 1999; Henderson and Buising, 2000). We are unaware of any recent survey of undergraduate teaching assistants in the sciences which sought to determine educational outcomes. Nevertheless, the role of graduate teaching assistants in the sciences has been examined (Druger, 1997; Sundberg et al., 2000), and surveys of teaching assistants have been performed in communications (Socha, 1998) and sociology (Fingerson and Culley, 2001).

Many science departments nationwide require that students complete an out-of-classroom experience in order to graduate. Undergraduates majoring in Botany at N.C. State University are required to complete either a teaching or research experience as part of the required departmental curriculum. Such

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experiences include (but are not limited to) laboratory teaching assignments in botany or biology courses, faculty-supervised research, and off-campus internships. We have developed a survey instrument to measure outcomes of teaching and research experiences in the Botany Department at N.C. State University. Results were used to determine what students did during their research/teaching experiences, educational outcomes, and the overall success of the requirement. Analysis of the results will be used to improve experiences and better advise students on which experiences to pursue in the future.

Methods

The survey instrument developed for assessing teaching and research experiences consisted of 60 multiple-choice items and 16 open-response items. The instrument's validity was assessed and improved by two experts (see Acknowledgements footnote), and its reliability improved by field testing with several students. We have posted this survey (www.cals.ncsu.edu/botany/faculty/gvandyke/undergraduatesurvey.html) for those interested in administering similar surveys at their institutions.

Botany majors at N.C. State University completed the survey individually after they had finished a research or teaching experience. Most students took about 15 minutes to complete the survey. A total of 25 surveys were completed from the fall of 2002 to the spring of 2004 which included student experiences over a three-year period (2001-2004). This constitutes the majority of the students who graduated from the Botany Department over this period.

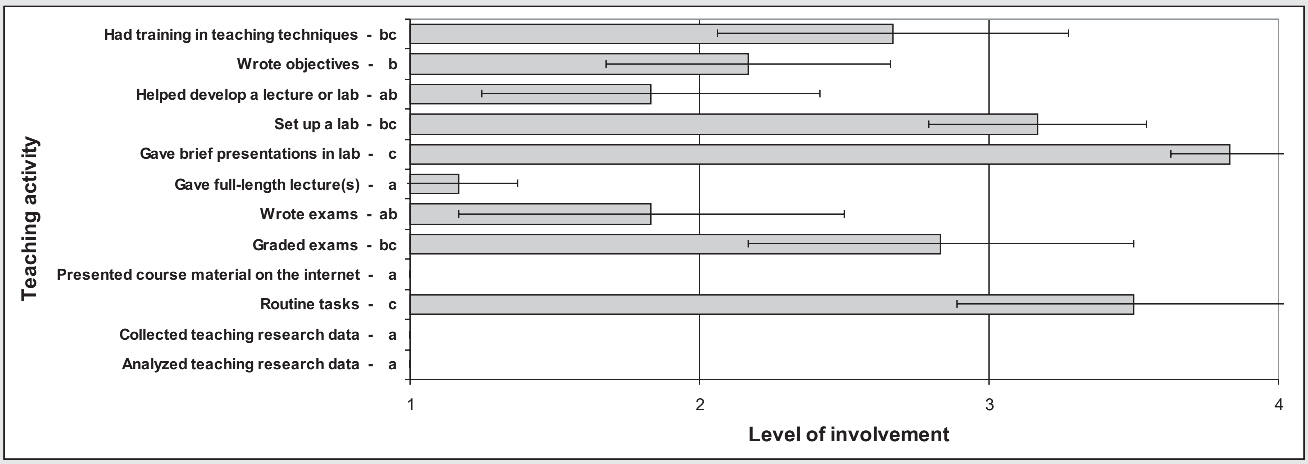

Figure 1. Average levels of student involvement in typical teaching-related activities in the Botany Department at N.C. State University, based on the following scale: 1 – not involved, 2 – somewhat involved, 3 – involved, 4 – very involved. The letters (a through c) indicate levels of involvement that differed significantly at p<.05. Error bars represent standard error. n=6.

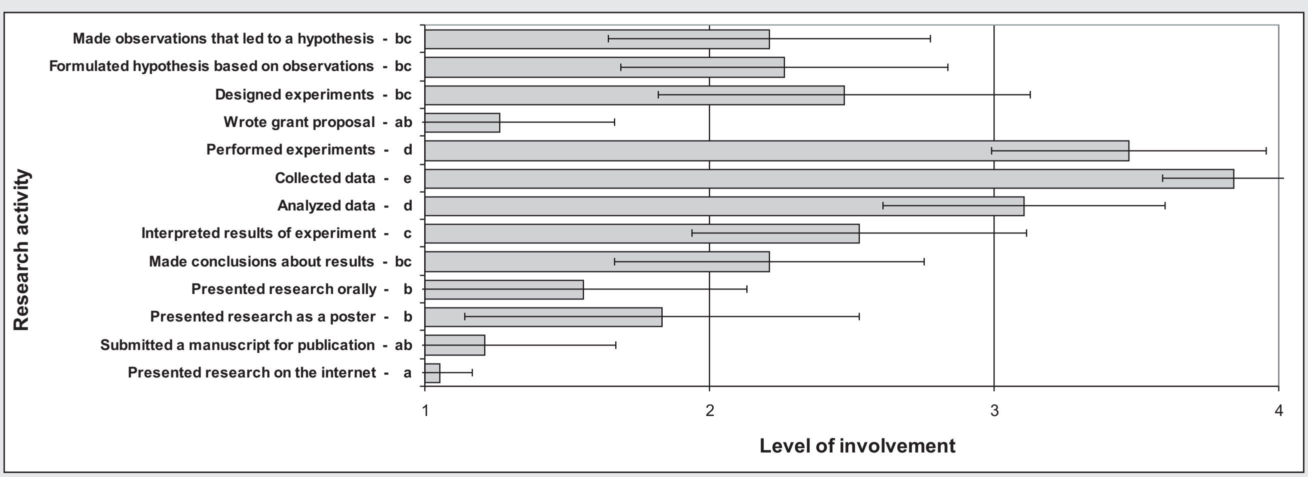

Figure 2. Average levels of student involvement in typical research-related activities in the Botany Department at N.C. State University, based on the following scale: 1 – not involved, 2 – somewhat involved, 3 – involved, 4 – very involved. The letters (a through e) indicate levels of involvement that differed significantly at p<.05. Error bars represent standard error. n=19.

Differences between responses were determined using a Student's t test.

Results and Discussion

Overview of the Students

The 25 students who completed surveys were Botany majors with an average cumulative grade point average of 3.5 on a 4.0 scale (ranging from 2.1 to 4.0). Students major in Botany at N.C. State University for many different reasons. The Botany curriculum is structured to allow students to customize their program in order to meet career objectives. Student interests included ethnobotany, molecular botany, pharmaceutical aspects of medicinal plants, plant ecology, plant identification (e.g. wetlands, rare and endangered plants, forest plants, and grasses), plant pathology, plant physiology, plant systematics, scientific writing, space biology, and many others.

Overview of Research/Teaching Experiences

Of the 25 students in this survey, 23 had one teaching/research experience, two had multiple experiences. Nineteen students performed research, six taught, and two had an experiential internship. Teaching experiences typically involved teaching assistant duties in Introductory Botany laboratories at N.C. State University. Research was performed in a broad array of settings: research labs on campus, Syngenta, BASF, Baylor College of Medicine, Reynolda Gardens at Wake Forest University, the U.S. National Arboretum, national forests, and the U.S. Department of Agriculture.

Typical teaching experiences occupied seven to ten hours per week for one or two semesters, and ranged from three to six hours per week for one semester to ten hours per week for three semesters. Typical research experiences during a school year occupied 10 to 20 hours per week for two semesters, whereas typical summer research experiences were 40 hours per week for the entire summer (9 to 12 weeks). The extent of research experiences ranged from eight to ten hours per week for one semester to ten hours per week for six semesters (including summer work).

Levels of Involvement in Specific Activities

Figures 1 and 2 show levels of student involvement in teaching and research-specific activities, respectively, using a 4-point scale. The most prevalent teaching activities were related to hands-on laboratory instruction, including set-up (3.2), brief presentations (3.8), and other routine tasks (Figure 1). Also, students were somewhat involved in other educational activities such as writing objectives (1.8), developing course material (1.8), writing exams (1.8), and grading exams (2.8). Few to none were involved in traditional professorial duties such as giving full-length lectures (1.2) or performing teaching research (1.0).

Students who participated in research reported being most involved in the processing of data, including performing experiments, collecting data, and then analyzing data (Figure 2). Moving from top to bottom along the y-axis of Figure 2 represents a typical progression of activities in a professional research setting. Students reported being somewhat involved in early research stages such as generating hypotheses (2.3) and designing experiments (2.5), and in late stages such as interpreting results (2.5) and making conclusions (2.2). The lowest-ranking categories were more advanced activities that demand a greater time commitment, especially involvement in the grant process (1.3) and presentation of research (1.1-1.8). Nevertheless, there was at least some student involvement in all stages of research (Figure 2).

Effects on leadership skills

General questions asked students about the effectiveness of their teaching/research experiences in helping them to “increase skills,” to “develop leadership skills,” and to “show them the need for developing leadership skills.” Students rated these at 4.2, 4.0, and 4.2 (on a 5-point scale), respectively, demonstrating that teaching/research experiences were effective to very effective at building leadership skills (Figure 3). Supporting evidence included many references to leadership skills among student comments regarding skills/rewards gained through a teaching/research experience. Skills noted were public speaking, time-management, self-organization, working with others, “asking for help,” “experiencing the dynamics of working with other members of the lab on a project,” and “thinking of different ways to accomplish a goal.”

The survey also contained questions that asked students to rate the effectiveness of their teaching/research experiences in developing nine particular leadership skills. Students rated effectiveness as follows (on a 5.0 scale): teamwork - 4.0, getting along with others - 4.0, problem-solving - 3.9, time-management - 3.9, analytical skills - 3.8, speaking - 3.4, writing 2.9, integrity - 2.9, and work ethic - 2.9. Therefore, students felt that teaching/research experiences were somewhat effective to effective in developing all nine leadership skills. The fact that none of the ratings for particular skills were quite as high as ratings for skills, in general, is probably related to students having many different types of experiences that enhanced different sets of skills. Thus, all experiences developed leadership skills, but each student developed a different combination of skills.

Most students felt that they already had integrity and a strong work ethic (Figure 3), thus any effects of research/teaching on developing these skills were minimal. The next two lowest categories, speaking and writing, were influenced by the low ratings of students with research experiences. Survey results

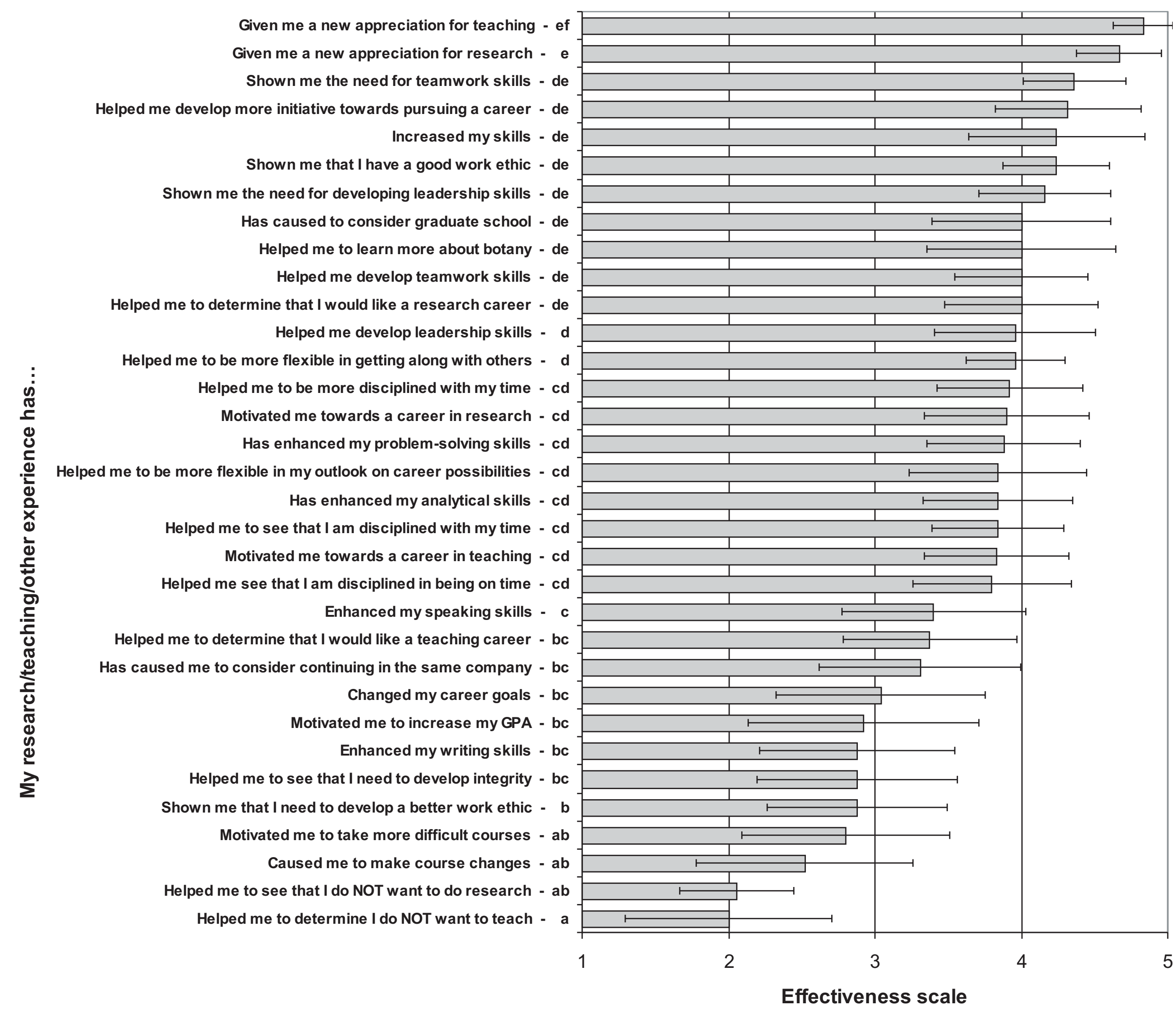

Figure 3. Student perceptions of their research and/or teaching experience in the Botany Department at N.C. State University, based on the following effectiveness scale: 1 – not applicable, 2 – not effective, 3 – somewhat effective, 4 – effective, 5 – very effective. The letters (a through f) indicate perceptions that differed significantly at $p<.05$. Error bars represent standard error. n=25.

are consistent in that activities that research students said they were less involved in (grant writing and presenting research) match the skills that they said were less developed by their experience (speaking and writing). We concluded that research experiences could be improved by putting more emphasis on speaking and writing, which equates to fostering environments where students will present their work.

Effects on academics and broader education

Immediate effects of teaching and research experiences on undergraduate academics were minimal (Figure 3). Most students found that experiences were either not effective or only somewhat effective at causing them to take different courses (2.5 on a 5.0 scale), motivating them to take more difficult courses (2.8), or motivating them to increase their GPA (2.9).

Nevertheless, student comments suggested that their experiences had a large impact on their educations. For example, one student wrote, "My research experience on campus has really made my education MUCH more well-rounded. I understand the things we are taught in class because I have done them. And what I learn in class supplements my understanding of techniques." Also, most students reported that their experiences were effective (4.0) at helping them learn more about botany. Combined, these data suggest that teaching/research experiences were educational even though they had little perceived effect on undergraduate academics.

Although teaching and research did not often cause students to change their undergraduate courses or improve grades, their experiences were effective (4.0) at causing them to consider further studies such as graduate school (Figure 3). This is ironic since academic achievement is necessary to get into graduate school. The trend of impacting future academic plans, while having little impact on current academics, may be related to most students having their teaching/research experiences as upperclassmen, and to their GPAs already being high (average 3.5). It is unclear how teaching/research experiences might affect the academic performance of underclassmen and/or a more random sample of the student population, where academics may have more room for improvement.

Effects on career goals

Students rated teaching/research experiences as somewhat effective (3.0 on a 5.0 scale) at "changing" their career goals (Figure 3), usually because they had already established goals. Student comments frequently referred to experiences "reinforcing", "refining", and "encouraging" with regard to their future careers, suggesting that their goals were being affected positively, although not changed.

Also, it appears that student attitudes toward pursuing a career were affected significantly (Figure 3). Students found that experiences were effective at helping them develop more initiative towards pursuing a career (4.3) and to be more flexible in their outlook on career possibilities (4.1). Interestingly, the more general effects on initiative were rated slightly higher than effects of motivating students specifically toward a career in teaching (3.8) or research (3.9).

Teaching/research experiences are potentially valuable for showing students what they will not be happy with as a career. This was an outcome for two students, one who would prefer to avoid research and another who is less likely to get a job in industry. Nevertheless, students on average found that their experiences were not effective at "helping them to determine that they did not" want to teach (2.0) or do research (2.1). In fact, these two categories were the lowest-ranking categories on the effectiveness scale (Figure 3). Although discovering what one does not like is a valid educational outcome, we view these scores as a further indication that teaching and research experiences are having a positive influence on students.

Summary

For college/university departments with teaching, research, and/or internship requirements, assessment can be very useful for improving experiences and better advising students. We found that students doing research in the Botany Department at N.C. State University are involved mainly in data collection and analysis, whereas those who are teaching are involved mainly with hands-on laboratory instruction. Nearly all students rated their experiences as very good overall and would recommend them to other students. Several positive educational outcomes were rated especially high, including a greater appreciation for teaching/research, greater initiative towards pursuing a career, an increase in skills, and greater consideration of graduate school. Students also found that the experiences were effective at building a range of "leadership skills", but rated academic-related outcomes relatively low. Our results have been used to determine what students did during research/teaching experiences, the educational outcomes, and the overall success of the requirement. This study has given us knowledge to improve particular experiences and better advise students on which experiences to pursue in the future. For example, students in Botany 101 will be shown outcomes of previous student teaching/research experiences so that they can better plan their own experiences. This study also serves as part of our department's assessment program for the university and has confirmed that undergraduate teaching and research experiences should be maintained in the curriculum. Because every department (and every student) is different, we anticipate that much of the value of this study lies in the actual survey instrument and strategy for analysis. Therefore, we invite others to adapt this assessment strategy in their own departments.

Literature cited

Boyer Commission on Educating Undergraduates in a Research University. 1998. Reinventing undergraduate education: A blueprint for America's research universities. <Http://naples.cc.sunysb.edu/Pres/boyer.nsf/>. Accessed 12 Aug 2004.

Chaplin, S.B., J.M. Manske, and J.L. Cruise. 1998. Introducing freshmen to investigative research A course for biology majors at Minnesota's University of St. Thomas. Jour. Coll. Sci. Teach. 27: 347-350.

Coker, J.S. and E. Davies. 2002. Involvement of plant biologists in undergraduate and high school student research. Jour. Nat. Resour. Life Sci. Educ. 31: 44-47.

Druger, M. 1997. Preparing the next generation of college science teachers. J. Coll. Sci. Teach. 26: 424-427.

Fingerson, L. and A.B. Culley. 2001. Collaborators in teaching and learning: Undergraduate teaching assistants in the classroom. Teaching Sociology 29: 299-315.

Henderson, L. and C. Buising. 2000. A research-based molecular biology laboratory. Jour. Coll. Sci. Teach. 30: 322-327.

Howard Hughes Medical Institute. 2002. Undergraduate science education at research universities. <Http://www.hhmi.org/news/091802b.html>. Accessed 12 Aug 2004.

Landrum, E.R. and L.R. Nelsen. 2002. The undergraduate research assistantship: an analysis of the benefits. Teaching of Psychology 29: 15-19.

Mabrouk, P.A. and K. Peters. 2000. Student perspectives on undergraduate research experiences in chemistry and biology. CUR Quarterly, Sept.: 25-33.

McLean, R.J.C. 1999. Original research projects A major component of an undergraduate microbiology course. Jour. Coll. Sci. Teach. 29: 38-40.

Miller, J.E., J.E. Groccia, and M.S. Miller (Eds.). 2001. Student-assisted teaching: A guide to faculty-student teamwork. Anker Publ. Co.: Bolton, MA.

National Science Foundation (NSF). 1996. Shaping the future: New expectations for undergraduate education in science, mathematics, engineering, and technology. <Http:www.ehr.nsf.gov/ehr/due/documents/review/96139/start.htm>. Accessed 12 Aug 2004.

National Science Foundation (NSF). 2004. Grant proposal guide (NSF 04-2).<http://www.nsf.gov/pubs/2004/nsf042/nsf04_2.pdf>. Accessed 12 Aug 2004.

Research Corporation. 2001. Academic Excellence: The Sourcebook. < http://www.rescorp.org/ae/ae_intro.html>. Accessed 12 Aug 2004.

Service, R.F. 2002. New lure for young talent: extreme research. Science 297: 1633-1634.

Socha, T.J. 1998. Developing an undergraduate teaching assistant program in communication: Values, curriculum, and preliminary assessment. Jour. Assoc. for Communication Admin. 27: 77-83.

Solomon, S.S., S.C. Tom, J. Pichert, D. Wasserman, and A.C. Powers. 2003. Impact of medical student research in the development of physician-scientists. Jour. Investig. Med. 51: 149-156.

Sundberg, M.D. and J.E. Armstrong. 1993. The status of laboratory instruction for introductory biology in the U.S. universities. Amer. Biol. Teacher 55: 144-146.

Sundberg, M.D., J.E. Armstrong, M.L. Dini, and E.W. Wischusen. 2000. Some practical tips for instituting investigative biology laboratories. J. College Sci. Teach. 29: 353-359.