



Research as the Path to 21st Century Skills

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Since 1938, the National Association of Biology Teachers (NABT) has promoted the adoption and dissemination of “best practices” in biology education, including authentic student research (see Watson 1957 for an early explicit example), at all levels. Today, more than a decade into the 21st century, we recognize the importance of biology education not only as a path to future employment in health care, biotechnology, and emerging research disciplines, but also for the nation’s citizenry who must make ethical, social, personal and professional decisions that affect themselves and society at large, both currently and in the future. As biology educators, we are transitioning from the National Science Education Standards to the Framework for K-12 Science Education (NRC 2012) and the Next Generation Science Standards, which will guide instruction at the pre-college level and prepare students for the revised college environment shaped by the guidelines outlined in reports like *Vision and Change* (AAAS 2010). While doing so, we see an increasing emphasis on treating scientific content and scientific practices as equal components of the well-designed instructional environment and on structuring education so it integrates these within and across disciplines, preparing students for careers where disciplinary boundaries are blurred and innovation is increasing.

What do these scientific practices include? They are the activities that biologists do to investigate the world around them: asking questions, creating and using models, experimenting, evaluating data and information, developing hypotheses (explanatory statements), thinking mathematically and computationally, arguing from evidence, and communicating (NRC 2012). Readers of this journal should clearly recognize these as the components involved in conducting research. It should also be clear that students will learn them best by engaging in these practices, reflecting on successes and failures, learning to judge their own competencies and receiving guidance from knowledgeable practitioners, proficient as researchers and mentors. By doing so, students should reach the goal of being able to perform science practices competently on their own in novel situations.

Should every student conduct research? Actually they do every day when they confront problems with unknown solutions, observations for which underlying causes are unknown, and propositions to evaluate. When the car doesn’t start or a MP3 player stops working, a student proposes an explanation or solution and tests it. Such simple examples require only a few rudimentary science skills and logical thinking, but they illustrate that science practices are directly imbedded in the lives of all students. As students take on adult responsibilities, it becomes pertinent to all of us that they can evaluate claims and data presented in organizational reports, marketing literature, political advertisements, jury trials, and ballots related to issues of climate change, teaching of evolution, stem cell research and use of animals or humans in research. These require not only content knowledge, but also an understanding of the nature of science and scientific research.

Does conducting research actually have the desired effects on students, e.g. improving their understanding of science or increasing the likelihood that they will obtain STEM degrees? A look at almost any of the multitude of studies at the high school and undergraduate level provides clear support, so a few examples should suffice here. Sadler et al. (2010) and Stake and Mares (2001) found positive effects on science career choices, including moving



away from choices of health professions toward the sciences as students became more aware of career options. Roberts and Wassursug (2009) examined a high school program's effects on students over a period of decades and found that students were significantly more likely to be actively engaged in research as part of their careers if they conducted research as high school students. A review of the research literature from half a century (Sadler, 2010) found positive influences on students understanding of the nature of science though it may be limited without explicit instruction (Bell et al. 2003). Charney et al. (2007) found increases in both content knowledge, an area of concern for many skeptics, and the understanding of science. However, because the effects of research participation can vary with the support the mentor provides, how much the collaboration occurs in the research environment, how much the student is allowed to contribute to the direction and design of the research, the degree to which the student understands the importance of the research results, and the personal interest a student has in the research (Burgin et al. 2012), it is important for teachers and researchers who may be participating in guiding the students to consider their roles carefully and seek out professional development opportunities to refine their skills at mentoring, which means more than simply directing or advising (COSEPUP 1997).

Education is a community effort that requires shared and specialized contributions. Thus we urge all teachers, scientists, administrators, and parents to support efforts to involve students in research not only in every science class, but through opportunities to participate in science fairs and in research labs. More specifically, teachers need to develop curriculum and rethink their teaching practices to incorporate science practices into the classroom and to individualize instruction so each student can find a research topic of interest and all students can understand how science practices led to what we know. Scientists should accept high school students (and teachers) as researchers in their labs, recognizing that mentoring involves offering grade-appropriate guidance, the opportunity for students to develop ownership in their projects, and developing a relationship with a student. To excel, teachers and scientists should engage in professional development through educational and scientific organizations such as NABT, who are aimed at structuring and conducting high quality research experiences for students. They should also seek to establish networks between high schools, universities or businesses, and policy makers to promote and facilitate student research opportunities. NABT BioClubs were envisioned as incubators for such relationships. Administrators should strive to provide the resources needed for students to engage in laboratory experiences that model science including space, time, equipment, supplies, and professional development. Parents should encourage their children, and demand from educators and administrators that science is for all, not just some. Students should embrace the challenge, look for the opportunity, and perfect the skills and reasoning that scientific research offers.

Students should also encourage each other, just as scientists do, by celebrating successes, consoling friends after failures, offering suggestions, accepting critiques, and sharing opportunities. Some of the rewards of research are immediate, some delayed, but all prepare you with the skills and habits of mind needed for the research-based decision-making that will lead to success the 21st century.

References

- AAAS. 2010. Vision and change in undergraduate biology education: A Call to Action. Washington, DC
- Bell, R L., Blair, L. M., Crawford, B. A. & Lederman, N. G. (2003). Just do it? Impact of a science apprenticeship program on a high school student's understandings of the nature of science and scientific inquiry. *Journal of Research in Science Teaching* 40(5): 487-509.
- Burgin, S. R., T. D. Sadler, and M. J. Koroly. 2012. High School Student Participation in Scientific Research Apprenticeships: Variation in and Relationships Among Student Experiences and Outcomes. *Research in Science Education* 42(3): 439 – 467.
- Charney, J., Hmelo-Silver, C. E., Sofer, W., Neigeborn, L., Coletta, S., & Nemeroff, M. (2007). Cognitive apprenticeship



- in science through immersion in laboratory practices. *International Journal of Science Education*, 29, 195–213.
- Committee on Science, Engineering, and Public Policy 1997. *Adviser, Teacher, Role Model, Friend: On Being a Mentor to Students in Science and Engineering*. National Academy Press: Washington, D.C.
- Craney, C. , T. McKay, A. Mazzeo, J. MorrisCross 2011. *Discipline Perceptions of the Undergraduate Research Experience*. *Journal of Higher Education* 82(1): 92-113.
- National Research Council: Committee on Conceptual Framework for the New K-12 Science Education Standards. 2012. *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. National Academy Press: Washington, D.C.
- Roberts, L. F. and R. J. Wassersug 2009. *Does Doing Scientific Research in High School Correlate with Students Staying in Science? A Half-Century Retrospective Study*. *Research in Science Education* 39:251–256.
- Sadler, T. S., S. Burgin, L. L. McKinney, and L. Ponjuan 2010. *Learning Science through Research Apprenticeships: A Critical Review of the Literature*. *Journal of Research in Science Teaching*, 47: 235–256.
- Stake, J. E. and Mares, K. R. 2001. *Science enrichment programs for gifted high school girls and boys: Predictors of program impact on science confidence and motivation*. *Journal of Research in Science Teaching* 38: 1065–1088.
- Watson, H. F. 1957. *Research by the High School Student*. *The American Biology Teacher* 19(5): 144-145.

Implementing Independent Student Research Programs for Teachers with a Lack of Research Experience

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The importance of inquiry has long been promoted in the scientific education community as crucial for developing competent STEM professionals. However, like any buzzword, many classroom teachers are artificially attributing what they do in the classroom as inquiry.

In my article *What Inquiry is NOT*, I share how I incorrectly categorized my class as such, when in fact it was not...and how I was able to develop a curriculum that truly was inquiry-based for my classroom. While there are varying levels of inquiry, the best way to provide fully-engaged, student-centered inquiry is to allow students to experience the scientific method from beginning to end from deciding the problem to communicating the results.

Teachers and professors who implement student independent research programs know that students gain not only laboratory skills and advanced science content knowledge, but also intangibles such as a better understanding of the nature of science, increased confidence in their ability to perform science, and an ability to learn scientific facts in context of something about which they are passionate. Yet, even though the number of teachers who believe inquiry to be the best way for their students to learn is growing, most remain unable to overcome the hurdles of implementing these opportunities for their students.



Though each teacher has specific reasons that might prevent the implementation of independent student research in the classroom, the most common hurdles generally fall into the following categories: 1) Teachers are uncertain of their ability to teach research; 2) Teachers feel they lack the resources and support to provide quality experiences for students; 3) Teachers are unsure whether students have the laboratory and critical thinking skills to perform such intensive research; and 4) Teachers are accustomed to having full control of curricular content and outcomes. In this article, I will address the first of these hurdles.

Classroom teachers often lack science research lab experience, which then leads to a lack of confidence when it comes to implementing independent student research. The problem for some teachers begins in their preservice teacher education programs. While the science lab courses they take along side pre-med and future researchers, it likely that unless they've sought out research opportunities, they've never focused on a single topic for an extended period of time. And teachers who attend graduate school often do so in education programs, not in their area of science, where any original research is in education and pedagogy-based research, instead of using the scientific method to study a scientific topic. This lack of science research experience is problematic for two reasons. First, it creates doubt in teachers' minds whether they have the skills and authority to guide students through their own scientific research projects—and the fear is well founded. Second, many career teachers have never written a scientific paper, and therefore may feel inadequate to guide students through this process.

Whether we want to admit it or not, those of us who are career educators have a different view of the scientific process than do career scientists. That's not to say that it should keep us from guiding students through the process of long-term research projects, but transparency regarding our weakness and skewed career-teacher perspective is healthy, not only for our own sanity, but also for the learning of our students.

The best way to address this issue is to provide research experiences for teachers. I was involved with two programs that became instrumental in my ability and confidence to implement semester-long student research projects with high school students. The National Science Foundation (NSF) has "Research Experiences for Teachers" or RET grants that encourage laboratory scientists to develop partnerships with K-12 teachers which include research experience for the classroom teachers. And NSF's Graduate Teaching Fellows in K-12 Education, (GK-12) was an NSF grant that funded projects that partnered scientists in graduate schools with classroom teachers. Instead of providing the teacher with research experience, it paired scientists with classroom teachers to develop curriculum that better mirrored how scientists conduct research. Any program or resource that bolsters teachers' confidence and helps them to face their assumptions about science research is crucial for creating a change in today's STEM classroom climate.

Not every teacher has the benefit of using an NSF program as a resource, so it is important that the teacher reach out to the scientific community directly. While teachers can be the sole expert contact for their students; students have a more intensive experience if paired with a research mentor. These mentors may be Principle Investigators or graduate students working in a university or industry lab. But mentors may also be online and work with a student from a distance to develop a strong research design. This relieves the teacher of having to be a content expert on every topic for each student. Instead, the mentor is the content expert, while the teacher provides a framework of the scientific method of which the student will need.

The lack of scientific research experience is also problematic because it means that most teachers have never written a scientific paper. Depending on the preservice teacher training, career science teachers may have turned in lab write-ups for their science courses, some of which may have been lengthy, but not the type of writing that would be turned into a scientific journal for publication. Teachers' writing experience—like their research experience—is heavily centered on educational philosophy. While teachers know the parts of a scientific paper and have read their share of scientific journal articles, writing on an extensive experiment which they designed and implemented is not a skill that most teachers have. Even if a teacher is confident regarding their own scientific research skills, a teacher may be uncomfortable having to teach literacy skills to his or her students. Traditionally, English departments have been responsible for teaching students prewriting strategies, library research skills, documentation styles, and editing multiple drafts of large papers.



Similar to addressing the lack of research experience, teachers can still provide strong experiences for their students by acknowledging their own weaknesses. Science teachers must reframe how they view their own responsibilities. The Common Core Science Standards emphasize critical thinking and the ability to apply knowledge over memorizing facts. Even for students who do not become STEM professionals, being able to sift through mountains of content to find answers to questions and being able to write and communicate succinctly are skills that will benefit students no matter what they decide to do. Therefore, teachers should seek out resources to help them teach basic research skills. English teachers and librarians are invaluable here as may be the STEM Student Research Handbook, as it is written to help guide both students and teachers through the entire research process. Students should be expected to write papers—worthy of publication—in journals such as JESS. This provides students with an audience beyond the classroom, and an understanding of how science knowledge is acquired.

So the question boils down to, “Can a teacher with limited research experience teach and guide students in the research process?” I believe teachers, even with their lack of science laboratory experience, can and should provide students with rich research opportunities.

Teachers who conduct research with their students need to communicate with the science education community. Teachers must share their experiences with other teachers. We must encourage one another, provide tips, point out pitfalls, and share resources. This communication can be accomplished by submitting articles for publication (like NSTA publications) and by presenting at conferences. Only when teachers realize that they are not alone in their fears of teaching research will they be encouraged to try. If more teachers address their assumptions about how science is really done, reach out to the scientific community, and place a newfound emphasis on communicating scientific results, the more likely we are to get real change in science education.