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Toward Enhancing Scholarship of Science Education in College Teaching

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Abstract

Quality of science instruction is crucial at the college level due to the increasing demand of scientific literacy. Development of science education has been examined in this article through both contextual and comparative angles of college teaching. Different approaches have been analyzed to merge interdisciplinary efforts that articulate both artistic and scientific natures for the benefit of various constituencies. Suggestions have been provided to enhance the scholarship of science education as a subject within natural science departments. Similar to the industry partnership between R&D and customer service sectors, effective collaborations between scientists and science educators can facilitate recognition of the science education subject across the campuses of higher learning.

Keywords: Science education research, discipline development, comparative studies.

With the ongoing expansion of global market and information technology, "Economic prosperity and success for individuals, families, cities, states, and countries are now being driven by the productivity of college educated workers and the industries that employ them" (Mortenson, 2009, p. 1). In particular, more specialized training is needed in higher education to support scientific inquiries that maintain the momentum of economic advancement. The demand on science teaching has become an international indicator of education quality in college settings (Rotberg, 1991).

In practice, science courses are frequently taught by science faculty in higher education. Despite program variations across the nation, the curriculum quality is essential for future scientist preparation and important for raising scientific literacy of students in non-science majors. Given the broad needs of science instruction, establishment of a subject status seems crucial to advancement and dissemination of knowledge in science education (Heron & Meltzer, 2005). Without a subject standing to streamline the knowledge accumulation, widespread teaching and learning issues often need repeated discoveries of similar solutions through trial-and-error methods in a disorganized manner.

While educational research is inseparable from the teaching practice, science educators

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have been spread over a number of departments according to their academic divisions. The department affiliation not only impacts the delivery of science teaching in a college setting, but also contributes to formation of stereotypic views on the entire community of science education. With the key stakeholders of faculty and students in the community, development of science education as an academic subject can be naturally linked to the scholarship recognition of science teaching across generations of science educators. Accordingly, the purpose of this article is to discuss latest efforts on the subject establishment from college science educators. Like the industry partnership between R&D and customer service sectors, effective collaborations between scientists and science educators represent a crucial step to support the subject-based research in college science teaching.

Scholarship in Science Teaching

Working in a science department, science professors may naturally consider science education a subject of science. For instance, physics educators have taken a position to declare physics education a sub-discipline of physics (Redish & Steinberg, 1999). In an effort of creating the subject status, Redish (1999) suggested that the results of research must be carefully documented and published, experiments must be repeated using different measurement tools, and other researchers must critically examine the results. Scholarly work disseminated in this way will allow science education research to reach the level of other research. The research rigor has supported award of Ph.D. degrees by science educators at several universities, and thus, made science education seemingly parallel to other graduate programs in science (Beichner et al., 1995).

Nonetheless, the department affiliation of science educators is a special feature of the university structure. At the levels of elementary or secondary education, biology, chemistry, and physics teachers are generally housed in a science division. Despite the contextual difference, a common goal of science teaching is to facilitate human development under various conditions, “ranging from large-enrollment classes at major public universities to small classes in two-year colleges and high schools” (Heron & Meltzer, 2005, p. 390). In this regard, research in science education primarily deals with student learning of the existing scientific knowledge, instead of advancing the frontier of science discipline. This unique characteristic fundamentally differentiates science education research from other investigations within natural science departments.

As science departments fulfill the dual missions of science education and scientific inquiry, effectiveness of science education is not solely grounded on knowledge competence within a science department. As Frank Richtmyer (1933), a founder of the American Physics Society (APS), pointed out, “That a knowledge of subject matter, however thorough that knowledge may be, is not of itself an entirely adequate preparation for teaching is at once recognized from the fact that there are many excellent scholars who are poor teachers” (p. 1).

To improve science education, understanding of student learning process is an important task that warrants additional research beyond the mastery of science. In industry, the customer service division not only disseminates the R&D results, but also supports understanding of the daily queries from various consumers. The linkage between *scientists* and *science educators* is similar to the relationship between *Research and Development (R&D) staff* and *customer service personnel*. While the R&D division provides technical knowledge for customer service, the consumer market expansion reciprocally generates resources to support the R&D enterprise. By the same token, the recognition of subject status can help the team building effort to enhance scholarship of science education in college settings.

In summary, teaching service and educational research are jointly imbedded in the interdisciplinary footing of science education. Bridging knowledge of humanities across the traditional boundary of science, science educators need the academic vision of contributing profound research in college teaching. Unless the scientific rigor has been fully endorsed by all the researchers, science educators might still face methodological futility, and thus, the subject status remains weak in scholarly inquiries.

Comparative Perspectives on Science Teaching

Higher education is not part of the compulsory education system in the U.S. However, the rich learning opportunities in science education may help attract students from other disciplinary domains. In particular, science educators are unique in their ability to establish scientific competency through higher education (National Research Council, 1996). In line with that mission, students should be allowed to transfer majors from *science* to *science education* within a science department that promotes both scientific discovery and science education. To date, that conduit does not seem to open widely at all major universities. For instance, Bruce Alberts, the former president of the National Academy of Science, reported an issue encountered by his daughter at Berkeley. When the student decided to switch major from biochemistry to science education, Alberts (1994) noted that "Her professors there – many of them my friends – made it clear that they could provide no help to someone who was thereby 'deserting science'" (p. 29).

In contrast, depleting of the learning opportunity is not a common practice in science education around the world. Almost equal in land areas, the U.S. and China are two comparable countries with the largest *developed* and *developing* economies, respectively. Both countries have faculty of science education affiliated in science departments. However, learning opportunities have been provided in China to support the transition of student majors from *science* to *science education* between undergraduate and graduate levels. In the physics department of Beijing Normal University, two professors of science education used to major in physics at the undergraduate level and changed to physics education at the Master degree level. Eventually, their doctoral degrees were awarded in areas of comparative education and educational psychology.

The additional knowledge from humanity subjects has strengthened Chinese educators' understanding of various issues in student learning processes. While subject competence remains a cornerstone of science educator preparation, Chinese educators prepared from the interdisciplinary programs are more adept in improving the introductory science instruction. In the U.S., it seems rather difficult for a science department to hire a tenure-track faculty who has no terminal degree in the subject field. Consequently, the humanity aspect was not fully considered in the U.S. educator preparation. As Redish and Steinberg (1999) observed, "Many physics faculty come away from teaching introductory physics deeply dismayed with how little the majority of their students have learned" (p. 24).

Among a wide range of courses in college science teaching, the introductory courses are often placed below the upper-division courses in the priority ranking of science department (Burnside, 2002). As more science courses are offered at this level for different majors, this is a research field involving a large number of science educators. The team expansion will create a positive condition to sustain peer reviews of the research literature for the subject establishment. Furthermore, the introductory college courses are adjacent to basic science courses in secondary education. Thus, research collaborations can be forged across different education levels to enhance longitudinal studies in science education (Heron & Meltzer, 2005).

Still, the domain of college teaching does not preclude similar learning problems with advanced courses in science (Hestenes, 1987). The doctoral program in physics education research (PER) at the University of Washington has included all academic requirements for doctorate in physics, except that the dissertation research deals with a PER problem (Aalst, 2000). The advanced coursework near the frontier of science might have increased U.S. science educators' opportunity to experience and understand the process of scientist preparation toward their terminal degrees. Without holding a Ph.D. in science, most Chinese science educators have not reached the scientific frontier. Hence, their role is more directed toward improving the public literacy in science.

In conclusion, science education is a research field that houses rich learning opportunities. While switching majors from science to science education might have stopped the Chinese science educators from reaching the frontier of science, the interdisciplinary training has increased their opportunities to better understand student-learning issues in general science education. The implication not only hinges on the designation of emphasis between *introductory* and *advanced* courses, but also results in the gathering of manpower in a common research field to bolster subject status of science education in college teaching.

Stereotypic Picture of Science Educators

Given the long history of science education since the mid 19^{th} century (Jenkins, 1985), stereotypic images might have been established to reflect a fact that "Pedagogical theory is generally held in low esteem by university scientists" (Hestenes, 1987, p. 440). Although science educators have been included in the professional community, national organizations like the *American Institute of Physics* tend to pool all the people who have no grant money in a category of physics education (Fuller et al., 1998). This practice might have portrayed an image of no scholarship for science educators through inadvertent extrapolation. Consequently, not all professors are willing to switch research focus from a scientific field to science education because "just doing teaching in a research oriented university is not enough" (Fuller et al., 1998, p. 153).

Isolated in a science department, some science educators can hardly get someone within their departments to review the merit of their professional preparation in science teaching. Instead, they have to set aside their interdisciplinary expertise, and pay more attention to science competencies that are narrowly valued by their colleagues in science. As Richtmyer (1933) pointed out, "The teacher, say, of science, must remember that though as a teacher he may be an artist, he is at the same time a scientist. He must approach the subject matter in his field always in the latter capacity" (p. 3). Accordingly, the priority of science department typically places scientific research first, followed by education of Ph.D. students, then Masters students, upper-level undergraduate majors and courses, introductory courses for majors, introductory courses for other scientists and engineers, and finally lowest of the low and often entirely absent, science for non-scientists (Burnside, 2002).

To overcome the feelings of low priority and professional loneliness, college science educators started sharing research findings across different science disciplines. In particular, chemistry educators presented their work at conferences of the American Association of Physics Teachers and physics educators reciprocated their research disseminations at the American Chemistry Society meetings. Regardless of the low priority on introductory courses in science departments, science educators have agreed to maintain a major emphasis in this area in the foreseeable future (Heron & Meltzer, 2005). The joint effort has promoted the status of science education as a professional subject, and curtailed impact of those departmental priorities against the concerted research in science teaching.

More Suggestions for Science Educators within a Science Department

Whereas it is important to recognize the value of science education in human development, the current climate in higher education is to promote scholarly inquiries in each subject domain. To break the academic isolation, science educators need to improve their status within science departments through enhancing the scholarship of science education. Some of the practical approaches, such as the ones suggested below, could be helpful in making science educators a welcomed addition by their colleagues in science:

1. Strengthening science education with scientific reasoning

   Instead of alienating scientists from science education, educators may consider practical steps to promote scientific reasoning in science teaching. Whereas textbook authors often tried to convince students to accept science concepts and principles, the instruction should not be confined in the knowledge memorization. Students could have the opportunity of engaging in scientific discovery or re-discovery of the existing knowledge base, including *involvement in argumentation discourse*, *development of counter-explanation*, *accumulation of rebuttal evidence*, and *justification of inquiry-based conclusions* (Watson, Swain, & McRobbie, 2004; White & Gunstone, 1992). Acar (2009) reported that the incorporation of active inquiries has brought science education closer to scientific explorations, and strengthened the professional alignment between science education and scientific research within the same department.

2. Streamlining mathematics preparation in science education

   Mathematical expressions provide a common communication tool for both scientists and science educators. Within the circle of scientists, the mathematics application could be solely focused on the scientific substance. In science education, however, mathematics applications must be customized to meet the level of student knowledge development. More specifically, the streamlining could be an issue because "the students less frequently draw upon physics concepts to inform their conceptualizations of derivative and integral" (Marrongelle, 2001, p. xviii). Through an epistemological lens, science educators can achieve a better match between mathematics presentation and student preparation (Bing, 2008). In this regard, both scientists and science educators share the same task of streamlining the available mathematics tools for scientific abstraction, definition, computation, and connection to physical reality (Sauer, 2000; Torigoe, 2008). The established student progress makes it easier for science educators to gain proper appreciation of their colleagues from the natural science domain.

3. Enriching lab experiences with the learning cycle designing

   Besides the needs of applying mathematics, scientific discoveries further depend on laboratory training. In contrast, the lab experiences in science teaching are primarily for demonstration or reconfirmation of textbook experiments, which tend to put students in a passive acceptance position (McBride, 2003; Renken, 2008; Rowley, 2006). To support the active learning in a lab setting, a 5E learning cycle includes "engagement, exploration, explanation, elaboration, and evaluation", and has been proven effective in enriching student lab experiences (Compbell, 2006; Gresser, 2006; Vreman-de Olde, 2006). Similar to the improvement of scientific experimentation by scientists, student lab skills can be enhanced through the ongoing learning-cycle advancement. This approach has gained support from well-known Berkeley physicists, such as Robert Karplus, because the "evaluation" of lab performance can lead to re-"engagement" of students in future experimentation (McCormick, 2000; Tweedy, 2005; Vertenten, 2002). Thus, science educators could take this approach to remedy the situation of isolation, and form alliance with scientists in improving the lab experiences for various students.

4. Upgrading the platform of science education with technological advancement

   While scientists are specialized in a particular subject, the platform of science education can be expanded through incorporation of information technology. For instance, using 3-D animations of physiological processes, students can accurately identify, describe, and quantify details and changes that characterize the kidney function. Science educators play an important role in enhancing their partnership with scientists, and launch innovative curriculum designs in biology. With $1.3 million grant from the National Institutes of Health (NIH), science educators at the University of Georgia have been praised highly by the university scientists for this technological advancement that not only facilitated the scientific demonstration, but also reduced the need of kidney organs in biological laboratories (Fosgate, 2008).

In summary, whereas the general foundation of science has been established by scientists, delivery of the knowledge in a classroom/lab setting relies on science educators. To customize science instruction for various students in higher education, subject-based research is needed in science teaching to cover the enhancement of scientific reasoning, integration of mathematics preparation, enrichment of lab experience, and incorporation of technological advancement. The suggestions provided here can be adapted by others within a discipline and across campus, and are designed to gain the indispensible support from science faculty toward a full recognition of science education as an academic subject. Alberts (1994) believes that scientists "can be educated away from arrogance and made to appreciate the real heroism of the many outstanding science teachers" (p. 31). If the professional partnerships can be established between R&D and customer service divisions in industry, we have good reasons to expect effective collaborations between scientists and science educators in advancing the endeavor of science education in the United States.

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