Support of Physics-Education Research as a Subfield of Physics: Proposal to the NSF Physics Division

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Submitted on behalf of the Physics Education Research Community by:

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Changing roles of physics

In the past few years, changes in the workplace and changes in the international political situation have resulted in significant shifts in the relation of physics as a profession to the society as a whole. Physics is being required both to justify its activities to the general public and to provide effective education for a broader segment of the population than ever before.[1] While many physicists have made strong efforts to improve communication with the public and to improve our educational system, many improvements have had limited effectiveness or practical utility. The demand for a better understanding of how to teach effectively and how to train new physicists in these skills is high. However, there is no "quick fix." Success, as in other fields, requires that the problem of teaching physics be regarded as a scientific research effort in which a body of principled knowledge is cumulatively created, tested, and refined.

Physics education research

In this context physics education research has, during the last fifteen years or so, emerged as a significant subfield of physics. Workers in the field have sought to address physics education itself more scientifically, aiming to address complementary intellectual and applied concerns. (A) They have engaged in research designed to gain a deeper understanding of some basic issues (e.g., understanding students' preexisting conceptions and naive ways of thinking, and understanding the thought processes needed to work in physics).[2] (B) They have built on the resulting insights to develop more effective teaching methods, to design innovative curricula, and to exploit educational applications of computers and other new information technologies.[3]

An increasing number of physicists have come to work in this emerging field of physics education. Small research groups active in this field now exist in several physics departments. Some of these have also been awarding physics Ph.D. degrees to graduate students whose thesis research has been in this area. For example, physicists from nearly twenty different universities came together at a recent special meeting on physics education research.[4]

Crucial role of physicists in this field

Physicists play a key role in this field of physics education research, even though they can and do profit from other work in education and the cognitive sciences.

(1) They have the sophisticated content knowledge essential to understand theoretical physics concepts and principles, to appreciate their significance, and to recognize the subtleties involved in their interpretation.

(2) Because of their own work in physics and their personal experience in teaching courses in this subject, they are uniquely well prepared to identify critical topics for research in physics education.

(3) Advances in technology (based on applications of sophisticated physics) are requiring the creation of new instructional materials that need a deep understanding of complex physics topics. The generation of such instructional materials, suitable for the introductory level, will require the collaborative efforts of experts in advanced physics with experts in student learning. Such collaborations are unlikely to be effective if the latter are unable to understand the relevant physics.

(4) Educational research findings, obtained by physicists in physics departments and published in some physics journals (like the American Journal of Physics) are much more likely to be heeded by most other physicists than other extant educational research.

(5) The transformation of research physicists into effective teachers, able to communicate effectively with a broad range of students, is also going to require the collaboration with experts in education. If these experts are not also physicists, the communication is unlikely to be effective.

(6) The advancement of education requires primarily an influx of good analytic talent. Physicists can here make a unique contribution by attracting bright well-trained graduate physics students to work on educational problems.

Problems hindering the development of the field

Several problems currently hinder the development of this field of physics education research and limit its potential contributions.

(1) Most existing groups in physics education research are below critical mass and have difficulties maintaining themselves. (Education groups above critical mass are mostly found in traditional schools of education and do not meet the crucial needs, listed above, that only physicists can provide.)

(2) Theses difficulties are aggravated because a researcher from the physics education community must currently patch together support from multiple NSF

Divisions (e.g., Research in Teaching and Learning, Undergraduate Education, Human Resource Development, Elementary Secondary & Informal Education). Such patchwork funding is troublesome and inefficient since the researcher must work with many different program officers and evaluation criteria.

(3) Most of these programs focus predominantly on curriculum development rather than on underlying research. They also aim to fund specific "projects" having identifiable goals and outcomes, but have little interest in supporting research groups that can promote the cumulative development of new knowledge. (By contrast, progress in fields such as nuclear or particle physics has often been fostered by NSF support of active research groups contributing to the field.)

Recently the NSF Physics Division has been led to support some educational activities. This is a very important effort and one that should be encouraged. However, in order for educational activities to contribute to a growing body of knowledge, they must follow the research model that has been so effective in other areas of physics. They must (a) be evaluated by experts in the field; (b) they must combine good physics with an analytical understanding of learning mechanisms and students' cognitive processes; (c) they must be well-documented, tested, and evaluated–and finally disseminated beyond the original site. It is only when all such elements are present that cumulative progress can be made as in other research fields.

Recommendations

At the previously mentioned meeting,[4] we have been designated as representatives to make specific recommendations on behalf of the physics education research community. As such, we recommend that the NSF Physics Division establish physics education research as a subfield of physics and support this field on a continuing basis in the same way as other research fields of physics (with proposals subjected to review by criteria similar to those in other research fields of physics).

We estimate the costs needed to support physics education research in this way as a subfield of physics would amount to about $2 million per year. (This number could support several active physics education research groups.) Such support might be achieved by reprogramming some of the existing funds currently aimed at education in the Physics Division and combining these with some (perhaps jointly managed) funds currently devoted to physics education with the Division of Education and Human Resources.

[1] “Undergraduate Science, Mathematics, and Engineering Education,” National Science Board report NSB86-100.

[2] McDermott, L.C. “Millikan Lecture 1990: What we teach and what is learned: Closing the gap.” *American Journal of Physics, 59,* 301-315 (1991); Mestre, J. P. “Learning and instruction in pre-college physical science.” *Physics Today, 44,* 9, 56-62 (Sept. 1991); Redish, E. F. “Implications of cognitive studies for teaching physics.” *American Journal of Physics, 62,* 796-803 (1994); Reif, F. “Scientific approaches to science education.” *Physics Today, 39,* 48-54 (Nov. 1986); Reif, F. “Millikan Lecture 1994: Understanding and teaching important scientific thought processes.” *American Journal of Physics, 63,* 17-32 (1995).

[3] Heller, P., Keith, R., & Anderson, S. “Teaching problem solving through cooperative grouping. Part 1: Group versus individual problem solving.” *American Journal of Physics, 60,* 627-636 (1992); Laws. P. “Calculus-based physics without lectures.” *Physics Today, 44,* 12, 24- 31 (Dec. 1991); McDermott, L.C. & the Physics Education Group at the University of Washington. *Physics by Inquiry*. (John Wiley, New York); Thornton, R.K. & Sokoloff, D.R. “Learning motion concepts using real-time microcomputer-based laboratory tools.” *American Journal of Physics, 58,* 858-867 (1990); Van Heuvelen, A. “Overview, Case Study Physics.” *American Journal of Physics, 59,* 898-907 (1991).

[4] The physics departments of ten of the universities represented at this meeting, held at North Carolina State University on Sept. 30 and Oct. 1 of 1994, now offer the Ph.D. degree in physics education (University of Washington, North Carolina State University, University of Maryland, University of Massachusetts at Amherst, Ohio State University, Arizona State University, Kansas State University, Rensselaer Institute of Technology, Montana State University, University of Nebraska).