Oersted Medal Lecture 2002: Reforming the Mathematical Language of Physics

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The connection between physics teaching and research at its deepest level can be illuminated by Physics Education Research (PER). For students and scientists alike, what they know and learn about physics is profoundly shaped by the conceptual tools at their command. Physicists employ a miscellaneous assortment of mathematical tools in ways that contribute to a fragmentation of knowledge. We can do better! Research on the design and use of mathematical systems provides a guide for designing a *unified mathematical language for the whole of physics* that facilitates learning and enhances physical insight. This has produced a comprehensive language called *Geometric Algebra*, which I introduce with emphasis on how it *simplifies and integrates classical and quantum physics*. Introducing research-based reform into a conservative physics curriculum is a challenge for the emerging PER community. Join the fun!

I. Introduction

The relation between teaching and research has been a perennial theme in academia as well as the Oersted Lectures, with no apparent progress on resolving the issues. Physics Education Research (PER) puts the whole matter into new light, for PER makes teaching itself a subject of research. This shifts attention to the relation of education research to scientific research as the central issue.

To many, the research domain of PER is exclusively pedagogical. Course content is taken as given, so the research problem is how to teach it most effectively. This approach to PER has produced valuable insights and useful results. However, it ignores the possibility of improving pedagogy by reconstructing course content. Obviously, a deep knowledge of physics is needed to pull off anything more than cosmetic reconstruction. It is here, I contend, in addressing the nature and structure of scientific subject matter, that PER and scientific research overlap and enrich one another with complementary perspectives.

The main concern of my own PER has been to develop and validate a scientific *Theory of Instruction* to serve as a reliable guide to improving physics teaching. To say the least, many physicists are dubious about the possibility. Even the late Arnold Arons, patron saint of PER, addressed a recent AAPT session with a stern warning against *any* claims of educational theory. Against this backdrop of skepticism, I will outline for you a system of general principles that have guided my efforts in PER. With sufficient elaboration (much of which