

Science Education Research vs. Physics Education Research: A Structural Comparison

Bayram Akarsu

School of Education, Erciyes University, Turkey

Email: bakarsu@erciyes.edu.tr

Abstract

The main goal of this article is to introduce physics education research (PER) to researchers in other fields. Topics include discussion of differences between science education research (SER) and physics education research (PER), physics educators, research design and methodology in physics education research and current research traditions and trends (e.g. current research ideas) within PER.

Introduction

Today's belief about teaching scientific concepts can be summarized with Floyd K. Richtmyer's statement "Teaching, I say, is an art, not a science" published in the first issue of the American Journal of Physics. In the first section of this article, research design, methods, purposes, and procedures of physics education research (PER) are elaborated and compared to that of science education. First of all, there is a common misconception concerning research areas of physics education among science educators. They often consider that physics education studies are constructed physics applications of science education, however, physics education is a separate branch of social sciences and somewhat related to pure physics because of its applications to teaching and learning concepts of physics.

Science educators are generally concerned with sharing science content and process with individuals not traditionally considered part of the scientific community. The target individuals may be children, college students, or adults within the general public. The field of science education comprises science content, some social science, and some teaching pedagogy. The standards for science education provide expectations for development of students' understanding through the entire course of secondary education. The traditional subjects included in the standards are physical, life, earth, and space sciences. Certainly, there is a relationship between science education and physics education but currently it is not as close as science educators suppose. We can certainly assert that physics education research was born from science education about a quarter century ago but current it is considered as a separate discipline. That is very akin to philosophy and science as they were, once upon a time, sources of all science materials and disciplines such as physics, chemistry, and biology. Typical research areas in science education include andragogy (learning strategies), concept learning, instructional design, teaching techniques, socioeconomic and cultural aspects of science, epistemology and nature of science and several other topics.

Nonetheless, physics educators are mostly interested in conceptual understandings of various topics of physics, social aspects, technological applications of computer software or other devices in the process of teaching physics, and educational materials.

Significance of physics education research can be discussed in three main features:

- 1- Physics Educators
- 2- Research Design and Methodology
- 3- Research Trends in PER

Physics Educators

Physics education research has become a valid research discipline independently from science education and physics for last two decades. Thus, a

physics educator characteristically holds either a science education or physics background. Some of old science educators or physicists, faculty who exclusively interested in instructional sides of physics, also converged to start investigating educational aspects of physics such as teaching strategies, technology usages in physics classroom, curriculum issues related to physics concepts. Early physics professors chose to isolate themselves from physics education in instructional and curriculum because similar to experienced teachers they do not want to improve themselves and put any effort to exercise more advanced teaching strategies and tools in their classes. That's a very typical characteristic of old and experienced educators and teachers.

Today, there exists a big controversy on where PER belong to: "Does it belong to science education departments or physics departments?" Actually, it can be appropriate to either department depending on the types of investigations. Studies conducted at college levels are usually done by physics departments because physics faculty members are familiar to complex and subtle aspects of topics in physics courses and they understand physics culture in college. Physics researchers looking into students' understanding typically aim to improve their conceptual understandings by content modification or other content related suggestions. One can also argue that most of the courses are taught by the same physics professors in the department. On the other hand, studies done by science educators generally investigate alternative teaching methods and strategies to improve the quality of physics education so they are interested in pedagogical side of physics teaching.

There exists another debate among physics educators and science educators on how to investigate college physics teaching. On one side, physics faculty claim that they possess adequate knowledge of both content and teaching physics concepts but science educators mostly see them as scientists rather than an educator. On the other side, most physicists strongly believe that science educators do not have enough level of content understanding because they don't have formal education of physics concepts.

Nonetheless, as PER specialists are able to conduct research, get research funding, recruit physics student, and give talks, they can become an excellent colleague among educators so physics educators are not only colleagues of science educators but also of curriculum specialists and cognitive developers. However, eventually they are physics educators who teach physics and develop teaching strategies for topics in physics. They understand various types of background physics students bring to the classroom and aim to teach both old and new concepts of physics to the next generations.

Research Design and Methodology

Current trends in physics education methodology show some similarities and differences compared to science education. For example, mixed method approach as well as in science education research is currently very popular approach to study topics in physics education research. The reason for why mixed methodology is used can be traced to main purposes of research issues in both disciplines. Commonly, conceptual developments of the students in general and in specific cases compose science education and physics education researches so both qualitative and quantitative methods are desirable to achieve that goal. Evidently, both qualitative and quantitative methods are also used to investigate topics in PER from different perspectives.

The oldest and possibly the most common research method until 1970s was quantitative approach which was inherited from anthropological and statistical studies. It is very useful when it comes to a large group of participants and to generalize the results of the study. In these studies, people generally use multiple-choice tests and that can be used and attained on a large scale. It owns high degree of both reliability and validity because of quantitative and statistical data but data can be biased if tests are not designed appropriately.

When researchers are working with small groups of students or faculty members or individuals, they usually choose to utilize qualitative approach since it can help them to investigate comprehensively the case or phenomena. However, this type of research

generates exceedingly rich and extremely large data set and main difficulty is that research findings cannot be generalized because low validity of data usually emerges. Some PER specialists have been using qualitative study since late 1990s. I believe more qualitative studies should be applied to PER to explore student's understanding thoroughly. Science education research utilized greatly more than PER. That way, why or how students think, act, and behave that way in a specific class in that environment can be answered case to case. Well, it is bad when it comes to generalize but which research type can be generalized well in social science? Therefore more and more qualitative studies should be used in PER.

Current Research Trends in Physics Education

Physics education research is not intended to only investigate and study content knowledge and curriculum design for physics. It also serve as a physics educator and focus on enhancing students' conceptual understandings of physics concepts through various science teaching strategies such as inquiry, discovery learning, active learning, and constructivist approach which were originally developed for science education specifically and never used for physics education.

PER experts are interested in several types of research: concepts learning, students' misconceptions and conceptual difficulties, epistemology of physics, technology aspects, instructional materials and curriculum development.

Conceptual knowledge studies of physics are currently most popular PER area. These research studies often focus on students' conceptual understandings of specific physics concepts for example their understandings of quantum physics, Newtonian mechanics, electromagnetism, optics and so on. Briefly, this area of physics education research investigates every types and level of physics topics. The earliest tests developed in PER are Force & Motion Conceptual Evaluation (FCME) (Thornton & Sokoloff, 1998), Electric Circuits Conceptual Evaluation (ECCE) (D. Sokoloff, 1993), and Test of Understanding Graphs - Kinematics (TUG-K) (Beichner, 1994). Conceptual issues in science education resemble ones in physics education but while physics

educators mostly deal with college level understanding of physics concepts science educators generally investigate elementary or secondary school environments of different science concepts including physics, chemistry or biology disciplines.

Students' misconceptions are perhaps second popular research area in PER. Some of physics educators focus on how misconceptions emerge in the process of learning physics. The main purpose of misconceptions lies in increasing students' understandings of physics, improving learning strategies, and advancing theoretical approach to teaching physics. Epistemology of physics is very similar to epistemology of science. In fact, there were compact before 1970s. Epistemology of physics investigates how students learn and how they conceptualize ideas of physics such as mental models, environmental issues, learning environments in the process.

Technological aspects of physics education can be considered more developed than ones of science education probably because physics requires more simulations and models therefore more computer software and simulations have been developed for physics educators such as atomic models and quantum models. In addition, MLBs (microcomputer-based labs) are intended to produce more deep understanding of physics concepts. Video-based labs (VLB) are also accepted as a technological tool for physics education. Several other tools are useful such as WebAssign, VBL, VPython, and SCALE-UP.

Finally, instructional materials are last issue for PER and maybe the most commercial side of physics education. The most popular and traditional textbooks are Fundamentals of Physics (Halliday, Resnick) and Physics (Walker) which are mainly designed to present topics in physics for freshman college level but do not include physics education aspects. Recently, some textbooks were published which reflect both physics content and teaching approaches such as The Physics Suite and Physics by Inquiry by Beichner. In contrast, science educator author science teaching textbooks from different perspective. They usually serve as secondary textbooks in science teachers preparation programs. Also, they focus on different science education research areas for instance including the nature of science, scientific models, and history of science. Physics education is a vital and fast-growing field of education and

physics educators contributed considerably to the area of educational research. Both experimental methods and theoretical models are developing.

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