FIGURE 2, expanded. Key issues, readings, and important questions for each period

A. Origins of physics education in the U.S., 1860-1884

Key readings: Spencer (1860), Huxley (1869), Youmans et al. (1881), Clarke (1881), Wead (1884); *Textbooks*: Quackenbos (1871), Steele (1878), Gage (1882)

Key issues:

(1) Physics was offered by a steadily increasing number of high schools.

(2) A majority of physics instructors professed support for the "inductive method" of instruction.

(3) A few schools began to incorporate individual student laboratory activities.

Questions to consider:

1. Despite the widespread support for the inductive method, there was very little individual laboratory instruction in physics up until this time. What can account for the enthusiasm for the inductive method when there were so few examples of courses taught in this manner?
2. Given that there were few specially trained instructors, and that textbooks and instructional methods strongly emphasized verbatim recall, what were realistic expectations for the outcomes of physics instruction?
3. What design principles motivated Gage's new textbook in contrast to older ones of Quackenbos and Steele?

B. The move toward laboratory science instruction, 1885-1902

Key readings: Hall (1887), NEA (1893), NEA (1899), CEEB (1901), Hall (1902), *Textbooks:* Hall and Bergen (1891), Carhart and Chute (1892), Woodhull and Van Arsdale (1901)

Key issues:

(1) Schools began to institutionalize laboratory physics instruction, which became very widely practiced—even dominant—by the end of the period.

(2) High school courses increasingly resembled college physics courses, with steadily increasing emphasis on mathematical formalism and precise, quantitative experiments.

(3) The Hall "Descriptive List" became the *de facto* standard for selecting experiments to be used in high school classrooms.

Questions to consider:

1. Why did individual laboratory instruction so suddenly (within 20 years) change from a marginal activity to a dominant and required activity?
2. What were the primary learning goals as expressed or implied by (a) Hall's Descriptive List (1887), (b) the NEA (1893) report, and (c) Hall's 1902 textbook on teaching? To what extent were these goals consistent with and/or contradictory to one another?
3. Although colleges began to require quantitative lab work, there were no general college entrance exams until 1901; what, then, could have accounted for the increasing formalization and mathematization of high school physics during this period?
4. How did the pedagogical philosophies used in the textbooks for this period compare and contrast with each other?

C. New Movement Among Physics Teachers, 1903-1910

Key readings: Mann, Smith, and Adams [Circular I] (1906), Circular VI (1908), Millikan (1906, 1909), Hall (1906a, 1906b, 1909), Mann (1909a, 1909b), Terry (1909), Dewey (1910a, 1910b); *Textbooks*: Millikan and Gale (1906), Mann and Twiss (1910)

Key issues:

(1) Increasing numbers of high school and university physics educators complained that the high school curriculum was becoming dominated by colleges.

(2) Only 40% of students were passing the college entrance exam. There was widespread dissatisfaction with the quality of high school physics instruction; "low quality" was attributed to excessive mathematical formalism along with an increasing number of topics, leading to overemphasis on memorization and rote procedures.

(3) The nationwide "New Movement Among Physics Teachers" began when a committee of one college physics professor and two high school teachers was appointed to take "steps as might seem desirable" to improve the quality of introductory high school physics.

Questions to consider:

1. Although reformers such as Mann expressed broad and diverse goals, they focused the questions in the New Movement "Survey" on specifying experiments and curricular topics; why did they do this, and what were the consequences of doing it?
2. What motivated the concerns and/or criticisms expressed by Hall and Millikan regarding the New Movement and its supporters?
3. Although many stakeholders expressed dissatisfaction with the current system, they had difficulty articulating clear, explicit, practical alternative actions. Why was this so difficult?
4. In what ways are Mann's and Millikan's philosophies about teaching reflected in their texts?

D. Project Method, and beginnings of PER, 1911-1914

Key readings: Mann (1912) [selected chapters], Mann (1913, 1914); *Textbook:* Black and Davis (1913a, b)

Key issues:

(1) The project method was seen as a strategy for making physics relevant to "everyday life."

(2) There was increasing recognition of a need for research in physics education.

(3) This was the final period of intense physicist involvement with high schools until the 1950s.

Questions to consider:

1. What was the "project method" as interpreted by Mann and Twiss (1910) and Mann (1912)?
2. What pedagogical issue(s) was the project method intended to address?
3. Does the Black and Davis text provide the necessary structure for implementing the strategies expressed in their Teachers' manual?

E. Reorganization of the secondary curriculum, 1915-1922

Key readings: Barber (1915), Downing (1915), Eikenberry (1915), Twiss (1915, 1920), Millikan (1916, 1917), NEA (1920), Eikenberry (1922) [Chaps. 4, 5, 6], *Textbook:* Dull (1922)

Key issues:

(1) The ever-growing emphasis on teaching "physics for everyday life" focused on technology and use of the project method.

(2) The rise of general science courses was promoted by science teacher educators but treated skeptically by some physicists.

(3) There was a growing gap between the skills needed for desired (project-focused) physics instruction and the actual, limited preparation of typical physics teachers.

Questions to consider:

1. Why do you think the educationists (Barber, Eikenberry, Downing, et al.) promoted general science and nature study?
2. What ideas did the physicists express about the general science course?
3. Contrast the ways in which the ***project method*** was conceived by the physicists and the educationists.
4. What did the educationists mean when they spoke of connecting science to students' lives?
5. What did the physicists (Twiss, Mann, Millikan, et al.) mean when they spoke of connecting physics to students' lives?

F. Dominance by educationists, 1923-1947

Key readings: Millikan (1925), Black (1930), Hurd (1930, 1932), Watkins (1932) [31st Yearbook], Beauchamp (1933), Kilgore (1941), Noll et al. (1947) [46th Yearbook], *Textbook*: Dull (1943)

Key issues:

(1) The "Cardinal Principles" of education and the physics [and technology] of "everyday life" were guiding themes in the evolution of physics curricula.

(2) Education faculty increasingly dominated discussions about physics education.

(3) Education literature expressed a strong perceived need for (but limited action on) research-validated curriculum.

(4) Serious concerns about improving physics teacher education arose in the 1930s and were amplified by post-World War II teacher shortages.

Questions to consider:

1. What issues were addressed in the physics education *research* publications of this period, and in what ways do those issues contrast with those of the present day?
2. How did the "physics of everyday life" as reflected in the textbooks and curricula compare and contrast to the themes enunciated in the NEA (1920) report?
3. How do goals and methods of physics assessment instruments of this period compare to those of the most recent period?
4. In what specific ways did the 31st and 46th Yearbooks either carry forward or revise themes enunciated earlier in the NEA (1920) report and the writings of the New Movement?

G. Re-engagement by physicists, rise of curriculum reform, 1948-1966

Key readings: Arons (1955, 1959), Zacharias (1960), Finlay (1962), Karplus (1964)
Textbooks: Dull (1955), PSSC (1960), PSSC Lab Guide (1960)

Key issues:

(1) There was a proliferation of federally funded, university-based "institutes" for in-service physics teacher education.
(2) After two decades of low involvement, university-based physicists re-engaged with efforts in high school physics curriculum development and physics teacher education.
(3) The PSSC curriculum was introduced and widely disseminated. It focused on core physics principles and lightly guided laboratory instruction, with influence from new guided-inquiry K-6 science curricula.

Questions to consider:

1. What were the similarities and differences between the ideas expressed by PSSC leaders and those of earlier reformers such as the New Movement, the NEA (1920) report, and the 31st and 46th Yearbook Committees?
2. What opinions regarding "traditional" physics education were enunciated by physicists involved with PSSC? What was the evidentiary basis for their opinions? Why do you think they maintained isolation from the science teacher education establishment of the period?
3. How do the PSSC curricular materials compare and contrast both to traditional materials of this period (e.g., Dull [1955]), and to materials and methods used in earlier periods?
4. What were the strategies and goals of physics teacher education and professional development adopted by PSSC? How do these contrast to those of the present day?

H. Culmination of post-war reforms and emergence of modern PER, 1967-1991

Key readings: Strassenburg (1968), NRC (1972), NRC (1973), Reif, Larkin, and Brackett (1976), Hestenes (1979), Viennot (1979), Trowbridge and McDermott (1980), Halloun and Hestenes (1985), Thornton and Sokoloff (1990), Laws (1991), Van Heuvelen (1991)

Key issues:

(1) Physicists initiated studies of students' reasoning abilities and general problem solving skills.
(2) Some physicists focused investigations specifically on student learning of physics.
(3) The first U.S. physics education research (PER) faculty positions appeared in university physics departments.
(4) NSF-funded science curricula were developed in university physics departments, including both K-12 curricula and research-based university-level physics curricula; both had a strong guided-inquiry conceptual emphasis.

Questions to consider:

1. How do the type and methods of engagement in physics education by Karplus, Arons, Reif, and McDermott contrast with each other? How did their activities set the stage for modern PER?
2. In what ways did modern PER reflect the intent of early reform movements?
3. What were some of the central themes of modern PER?

I. Rise of conceptual physics and of modern PER, 1992-2001

Key readings: Heller, Keith and Anderson (1992), Heller and Hollabaugh (1992), AAAS (1993) [Benchmarks], NRC (1996) [Standards], Redish (1994), Reif (1995), Wells, Hestenes and Swackhamer (1995), McDermott (2001)

Key issues:

(1) There was a dramatic and steady rise of enrollment in high school conceptual physics courses.

(2) AIP surveys showed that physics content background of high school teachers was steadily increasing.

(3) There was a significant increase of research-based active-learning physics instruction at the college level.

(4) A broad-based PER community began to develop in university physics departments.

(5) Standards in science education were developed by AAAS and NRC, with attention to specific content standards, common themes among disciplines, and processes of scientific inquiry.

Questions to consider:

1. What were the main perspectives on learning adopted implicitly or explicitly in the PER literature during this time? How were these perspectives applied?
2. Why did PER of this period focus on students' understanding of physics concepts, while conceptual understanding had been relatively so little emphasized in earlier education research?
3. What are some of the specific instructional methods discussed in the literature, and what evidence do authors provide to support claims about the effectiveness of these methods?

J. The present day: High school physics, national reports, 2002-2017

Key readings: NRC (2006) [America's Lab Report], Committee on Prospering (2007), PCAST (2010), Meltzer, Plisch and Vokos (2012), NRC (2012) [Framework], NRC (2012) [DBER], NRC (2013); NGSS (2013)

Key issues:

(1) The number of PER PhDs increased along with the number of Discipline-Based Education Research efforts at universities.

(2) Moves to assess and improve physics teacher quality were on the rise nationally.

(3) A new generation of national science education standards was developed, which incorporated an emphasis on "science practices."

Questions to consider:

1. What are some of the reasons the NRC (1996) "Standards" and AAAS (1993) "Benchmarks" have had only limited national impact, and how do the NGSS (2013) Next Generation Science Standards claim to be different?
2. In what ways and to what extent have research-based curricula found their way into classrooms at different grade levels (e.g., K-8, 9-12, post-secondary)?
3. What is "discipline-based education research"?
4. What are some of the basic findings of physics education research regarding effective methods for teaching and learning physics?

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