Globalizing Physics

One Hundred Years of the International Union of Pure and Applied Physics

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OXFORD
UNIVERSITY PRESS

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Great Clarendon Street, Oxford, OX2 6DP,
United Kingdom

Oxford University Press is a department of the University of Oxford.
It furthers the University's objective of excellence in research, scholarship,
and education by publishing worldwide. Oxford is a registered trade mark of
Oxford University Press in the UK and in certain other countries

Published in the United States of America by Oxford University Press
198 Madison Avenue, New York, NY 10016, United States of America

British Library Cataloguing in Publication Data
Data available

Library of Congress Control Number: 2023952141

ISBN 9780198878681

DOI: 10.1093/oso/9780198878681.001.0001

Printed and bound by
CPI Group (UK) Ltd, Croydon, CR0 4YY

Contents

Preface

The year 2022 marked the centenary of the International Union of Pure and Applied Physics (IUPAP), the only international scientific union for all branches of physics, organized and run by the physics communities of the world. The centenary provided an opportunity to celebrate, to reflect on the Union's past and present, and to discuss its future. Reflection on the past played a key role. Knowledge on an organization's history helps to shape its collective identity, to create a sense of community and continuity, to develop an appreciation of those who have come before, and to point the way to improvement and informed decisions. In this context, the publication of the book *Globalizing Physics: One Hundred Years of the International Union of Pure and Applied Physics*, edited by Roberto Lalli and Jaume Navarro, marks a milestone in the history of our Union, which will undoubtedly be of great value to the communities of physicists and historians, as well as to the general public. We are indebted to Roberto, Jaume and all the authors who have explored the steps taken by IUPAP since its foundation, highlighting the key role of physics in the development of new technologies and the relevance of our Union for science diplomacy throughout its century of existence.

This book is the result of a somewhat unexpected combination of events that came together perfectly, leading to its publication and other results with implications for our Union. In 2018, we approached Roberto Lalli, who had, among other things, written an article on the foundation of the European Physical Society,[1] to see if he could be interested in working on some aspects of the history of the Union on the occasion of the centenary. Roberto immediately showed great interest in the project, which was closely related to his research activities. At the time, however, he was involved in other research projects, and it was not at all clear whether he would be able to commit to working on the history of IUPAP. Luck was on our side and Roberto was finally able to join the effort. It was immediately clear that access to IUPAP's digitized archival material was essential to progress. Under Roberto's guidance and thanks to his extensive professional network, in about a year we were able to complete the full digitization and indexing of the IUPAP institutional archives, which were located in several places around the world: from the IUPAP Gotheborg Secretariat at the Royal Swedish Academy of Sciences, Stockholm, to the Larkin Kerwin Fund at Laval University, Quebec, and other diverse printed materials available in various collections at the University Sapienza, Rome, at the Massachusetts Institute of Technology (MIT), and at Caltech. These invaluable resources for historical research will soon be made openly available on the web. Separately, the officers of IUPAP have been discussing the possibility of creating a new Commission on the History and

[1] Roberto Lalli, "Crafting Europe from CERN to Dubna: Physics as Diplomacy in the Foundation of the European Physical Society," Centaurus 63, no. 1 (2021), 103–31 https://doi.org/10.1111/1600-0498.12304.

units of radioactivity ended up being mainly the responsibility of more appropriate international bodies, such as the BIPM, ICRU, or the ISO. Joint Commissions, and especially the topic of radioactivity and nuclear sciences were now dispersed across many national transnational and international agencies and multiparty ventures, and the international scientific organizations such as ICSU no longer held the monopoly of coordinating nodes of overlapping interest and expertise. The time of Joint Commissions had passed, beyond the inadequacy reached by the specific trajectory of the Joint Commission for Radioactivity.

Acknowledgments

Special thanks are due to staff of the *Musée Curie*, Paris, who kindly made its collection of the Curies' and Joliot-Curies' papers available to the authors, and to the Othmer Library of Chemical History, Science History Institute, Philadelphia, which has granted access to the IUPAC Archives over the years.

6

Restoring Physics

IUPAP's Commission on Education, Signature Pedagogies, and the Inter-National Politics of Science in the 1960s

Josep Simon

Between the late 1950s and early 1960s a series of initiatives in different parts of the world aimed at changing how physics was taught. Concerns about the outdated nature of physics teaching and its differentiated national character were considered an obstacle to the restoration of physics' universality for the sake of professional, social, and economic progress. Accordingly, a series of international conferences were planned through organizations such as the International Union of Pure and Applied Physics (IUPAP), the United Nations Educational, Scientific and Cultural Organization (UNESCO), the Organization for European Economic Co-Operation (OEEC; later OECD, Organization for Economic Cooperation and Development) and the Organization of American States (OAS). Concurrently, meetings were held in national contexts and some national projects developed their own internationalization strategies.

In 1960, IUPAP organized its first International Conference in Physics Education in Paris (with UNESCO and the OEEC) and appointed an ad hoc permanent Commission. Three years later, in Rio de Janeiro, its second conference (with UNESCO and the OAS) gathered physicists and educators from across Latin America. Conferences discussed issues from curricula and training strategies to laboratory work and new educational means. While emphasizing the universal benefits of science, they coupled pedagogical innovation to the politics of the physics profession, economic recovery after World War II, development, and national sovereignty. They were also public representations of behind-the-scenes interactions to reshape both physics and society that involved boundary work, diplomacy, and the demarcation between scientific and pedagogical knowledge, across geopolitical scales.

In this paper, I analyze these IUPAP conferences and the early workings of its Commission on Physics Education. First, I discuss the relevance of studying physics as a profession shaped in the pedagogical battlefield. Second, I provide an overview of the organization of these conferences and commissions. Third, I analyze their contents and dynamics. Finally, I characterize the signature pedagogy of post-war physics and its role in the making of physics as a profession.

Josep Simon, *Restoring Physics*. In: *Globalizing Physics*. Edited by: Roberto Lalli and Jaume Navarro, Oxford University Press.
 DOI: 10.1093/oso/9780198878681.003.0007

Physics as a Profession

Physics has rarely been discussed as a "profession." It is usually portrayed as a disciplined body of knowledge that emanates from universities as well as from national and international (disciplinary) societies controlled by university physicists. Occasionally, we admit that it has fundamental intersections with other disciplines such as chemistry and engineering, and tend to differentiate this type of physicists as "professional"—in a restrictive sense meaning "industrial" or "applied."[1]

That physics is a profession—in an unrestricted sense—is evident, unless we believe that universities are not employment bodies, but immaterial temples.[2] In addressing the workplace and the marketplace, the "profession" offers a stronger socio-political perspective than the "discipline." It comprehends not only a knowledge base but also a code of ethics, performance standards, regulatory and organizational practices and a group identity. Thus, we are able to focus "not on knowledge alone but on the professional groups representing disciplines or bodies of knowledge that claim the right to control particular areas of social policy that affect particular areas of human life."[3] The "profession" concept has been relevant for historians of medicine, engineering and chemistry who have characterized the emergence of national communities of specialized workers and the tensions across the scientific and technical professions.[4] It is a useful tool for the analysis of the interactions between the physicists, engineers, science teachers, educationists, psychologists, government officials, and organization and corporation representatives attending the aforementioned conferences.

Traditional views assume simplistic dichotomies between "pure" and "applied," "university" and "industry," "research" and "teaching." A discipline (physics) would

[1] An exception is Yves Gingras, *Physics and the Rise of Scientific Research in Canada* (Montréal-Kingston: McGill-Queen's University Press, 1991). As he argues, most authors do not focus on the "profession" or use the term superficially. Examples of this are Daniel J. Kevles, *The Physicists: The History of a Scientific Community in Modern America* (New York: Alfred K. Knopf, 1977); Dominique Pestre, *Physique et physiciens en France, 1918–1940* (Paris: Editions des archives contemporaines, 1984); Paul Forman, John L. Heilbron, and Spencer Weart, "Physics circa 1900: Personnel, Funding, and Productivity of the Academic Establishments," *Historical Studies in the Physical Sciences* 5 (1975): 1–185; Iwan Rhys Morus, *When Physics Became King* (Chicago: University of Chicago Press, 2005). On physics as a discipline see Josep Simon, "Writing the Discipline: Ganot's Textbook Science and the 'Invention' of Physics," *Historical Studies in the Natural Sciences* 46, no. 3 (2016): 392–427.

[2] John D. Bernal, *The Social Function of Science* (London: George Routledge & Sons, 1939), 9–10; Edward Shils, "The Profession of Science," *The Advancement of Science* 24, no. 122 (June 1968): 469–79.

[3] Eliot Freidson, *Professional Powers: A Study of Institutionalization of Formal Knowledge* (Chicago: University of Chicago Press, 1986), ix.

[4] See John C. Burnham, *How the Idea of Profession Changed the Writing of Medical History* (London: Wellcome Institute for the History of Medicine, 1998); Colin A. Russell, Noel G. Coley, and Gerrylynn K. Roberts, *Chemists by Profession: The Origins and Rise of the Royal Institute of Chemistry* (Milton Keynes: Open University Press [for] the Institute, 1977); Gerald L. Geison, *Professions and the French State, 1700–1900* (Philadelphia: University of Pennsylvania Press, 1984); Jack Morrell, "Professionalisation," in *Companion to the History of Modern Science*, ed. Robert Olby, Geoffrey N. Cantor, John R. R. Christie, and M. Jonathan S. Hodge, (London: Routledge, 1990), 980–9; Colin F. Divall and Stephen F. Johnston with James Donnelly, *Scaling Up: The Institution of Chemical Engineers and the Rise of a New Profession* (Dordrecht: Kluwer Academic, 2001); Sean F. Johnston, *The Neutron's Children: Nuclear Engineers and the Shaping of Identity* (Oxford: Oxford University Press, 2012).

be defined by "pure" knowledge produced in universities governed by research and subsequently transferred to industry and teaching.[5] This is a platonic vision, a labor organization scheme bestowing the top of the disciplinary and professional pyramid on university research physicists. It is unsustainable when we acknowledge the epistemological relevance and differential status of engineers' and teachers' ways of knowing, the relationships between university, disciplinary practices, and industry, and the feedback between research and teaching.[6]

According to David Kaiser, university enrolments and the Cold War problem of scientific manpower shaped in the United States not only "a less overt, yet longer-lasting form of politicization for the nation physicists," but also—through pedagogy—a different "American physicist's style of work." This phenomenon shaped "[p]hysicists' attitudes and judgements about what counted as appropriate topics for research and teaching."[7] Kaiser falls short, though, in interpreting its consequences for the physics discipline and profession. John Rudolph has emphasized the relationship between the 1960s new science education projects and the "professional desires of the American scientific community."[8] Research physicists turned to educational research to keep their funding while preserving their autonomy and refashioning their public image. This entailed collaboration with physics teachers and educational researchers, but also tensions. These tensions, I argue, were related in fundamental ways to dynamic processes of professional formation affecting these actors.

In line with Lee Shulman, I propose to place the focus of disciplinary and professional formation in the foundational role of pedagogy "in shaping the character of future practice and in symbolizing the values and hopes of the professions." I engage with his concept of *signature pedagogies* as the specific ways of teaching characterizing particular forms of professional preparation and "the three fundamental dimensions of professional work—to think, to perform, and to act with integrity," and I apply it to physics.[9] I contend that professionalization did not only happen in the national context, but was especially forged at the international level. Thus, I suggest the relevance of a focus on physics as a profession and on educational debates as expressions of the anxieties of professionalization among a wide range of actors.

[5] On the distinction between pure and applied physics in IUPAP's history see Martin's chapter in this volume.

[6] Daniel S. Greenberg, *The Politics of Pure Science* (New York: New American Library, 1967); Eugene S. Ferguson, *Engineering and the Mind's Eye* (Cambridge, Mass: MIT Press, 1992); John V. Pickstone, *Ways of Knowing: A New History of Science, Technology and Medicine* (Manchester: Manchester University Press, 2000); Terry Shinn, "The Industry, Research, and Education Nexus," in *The Cambridge History of Science*, vol. 5, ed. Mary Jo Nye (Cambridge: Cambridge University Press, 2003), 133–53; Kathryn Olesko, "Science Pedagogy as a Category of Historical Analysis: Past, Present, and Future," *Science & Education* 15, nos. 7–8 (2006): 863–80.

[7] David Kaiser, "Cold War requisitions, scientific manpower, and the production of American physicists after World War II," *Historical Studies in the Physical and Biological Sciences* 33, no. 1 (2002): 131–59, on 133–4.

[8] John Rudolph, *Scientists in the Classroom: The Cold War Reconstruction of American Science Education* (New York: Palgrave, 2002), 7.

[9] Lee S. Shulman, "Signature Pedagogies in the Professions," *Daedalus* 134, no. 3 (2005): 52–9, on 52–3.

American Hegemony and the Post-War Restoration of Physics (Education)

IUPAP's 1960 conference gathered delegates from twenty-eight countries in UNESCO's premises.[10] Europeans were the most numerous, with around four delegates from each of fourteen Western European countries and two delegates from each of five socialist European states (Czechoslovakia, Hungary, Poland, USSR, and Yugoslavia). Asia was only represented by Japan, Turkey, and the United Arab Republic; Latin America, by Chile and Mexico; the African continent, by South Africa; and Oceania, by Australia. The smallest representations were from Austria, Spain, Greece, Turkey, Czechoslovakia, Chile, Mexico, and Australia; the largest, from France (eight) and the United States (nine). There were also representatives from UNESCO, the OEEC, the International Atomic Energy Agency (IAEA), and the (US) National Science Foundation (NSF). The size of each delegation was determined according to the "number of contributory units donated" to IUPAP, aiming to represent "a rough measure of the development of physics and physics teaching" in each country.[11] It also depended on relative economic and political muscle: the highest monetary contributions were by the USA and USSR, followed by the UK, France, Italy, and West Germany.[12]

The conference was chaired by Sanborn Brown (physics professor at the Massachusetts Institute of Technology (MIT)) and Norman Clarke (a Bachelor of Science from the University of Manchester representing both the (British) Institute of Physics and the OEEC). According to Brown, the Paris conference resulted from conversations between him and William Kelly (head of the brand-new education department of the American Institute of Physics (AIP)) in the summer of 1958. Both had served in the committee on Apparatus for Educational Institutions of the American Association of Physics Teachers (AAPT). They allegedly realized that US physics teaching could benefit from international comparison, especially with Europe. Receiving AAPT support, Brown convinced IUPAP to plan an international conference. He then formed a committee with experienced physicists from the UK (Norman Clarke), Germany (Werner Kroebel), France (Pierre Fleury, as the IUPAP Secretary General, and Louis Weil, as the OEEC representative), Italy (Enrico Persico), Japan (Toshiro Kinbara), the USA (Elmer Hutchisson, AIP President), and UNESCO (Hilliard Roderick,

[10] Among IUPAP national members, only Bulgaria, Romania, Egypt, Israel, India, Pakistan, The Republic of China, New Zealand, Argentina, and Brazil did not send delegates. Greece, Turkey, the United Arab Republic, and Chile were not IUPAP members, but they sent delegates. The delegate of Chile was in fact a UNESCO officer.

[11] Sanborn C. Brown and Norman Clarke, "Preface," in *Proceedings of the International Conference on Physics Education* (Norwood, MA—New York: The Massachusetts Institute of Technology—John Wiley & Sons, 1960), v–viii, on v–vi.

[12] Larkin Kerwin, "The International Union of Pure and Applied Physics," *Physics Today* 22, no. 5 (1969): 53–5; G. R. Laclavère to Secretaries General and Treasurers of all the Unions, May 6, 1965; Larkin Kerwin, "IUPAP list of National Committees 1965;" Larkin Kerwin to G. Laclavère, May 26, 1965; H. W. Thompson, "I.C.S.U. Appeal," May 8, 1965, Fonds Larkin Kerwin, IUPAP series P202/B4, folder 34 "International Council of Scientific Unions, ICSU 1966–1984," Archives Université Laval; Larkin Kerwin to the chairman of IUPAP National Committees, November 3, 1965, series E1 "Larkin Kerwin's and Pierre Fleury's correspondence," vol. 1, folder 3 "Argumentation des parts 1969–1974," IUPAP, Quebec Secretariat, Center of History of Science, Royal Swedish Academy of Science (hereafter IUPAP Quebec).

Stanford nuclear physicist and Foreign Service Reserve Officer).[13] In the meantime, the AIP President had contacted IUPAP's President (Edoardo Amaldi) with a similar proposal. Secretary General Fleury agreed with Hutchisson on their common interest to strengthen collaboration between physics and teachers' societies (highlighting two fundamental sides of the physics profession).[14]

The US delegation at the Paris conference included physicists serving in the AAPT, in executive positions or in special committees. Most of them worked as physicists in engineering schools and were used to receive funding from both federal agencies and corporations. Some of them were renowned textbook authors (e.g., Francis Sears). Others, such as Francis Friedman and Jerrold Zacharias (the Physical Science Study Committee (PSSC)), and Harvey White (Continental Classroom) led educational projects shaped by the frenzy of topical technologies (film and television). Some of them had participated in a series of national conferences for the improvement of physics teaching organized in the USA since the mid-1950s.[15]

IUPAP's conference followed the model of previous US conferences in many ways partly due to the larger number of US delegates, including an NSF representative and US physicists in UNESCO and IAEA positions, even to the extent of surpassing the French hosts. It is almost certain that there was a concerted joint operation of this national community of physicists. They had institutional and professional relationships, which in certain cases dated back from their engagement in the World War II military effort and, later, in educational reform. In 1960s America, the network of physicists involved simultaneously in educational projects, professional societies, scientific foundations, and governmental advisory committees was closely tight and prone to revolving doors and cronyism.[16]

Months earlier, the OEEC released the report *A Modern Approach to School Physics* for discussion at the conference. It was produced by a "Group of Experts" (coordinated by Clarke), some of whom would join IUPAP's Commission on Physics Education (Clarke, Antonius Michels, Daniele Sette). Others were part of the Paris conference organizing committee (Clarke and Weil). The conference resolutions established that such a commission should be set "possibly in collaboration with other international organizations," as "an international committee of professional physicists." It would conduct evaluative international surveys on physics education (at all levels), develop experiments in physics teaching improvement, review the

[13] Brown and Clark, "Preface," v–viii; William C. Kelly, "Witness at Creation: I.C.P.E.'s Founding and Early Years," in *I.C.P.E. Histories*, comp. E. Leonard Jossem, 1985–88, series B4 "Essays of IUPAP's activities," incl. its commissions," vol. 1, IUPAP, Gothenburg secretariat (hereafter IUPAP Gothenburg), Center of History of Science, Royal Swedish Academy of Science; United States Department of State, "Obituaries: Hilliard Roderick," *State. The Newsletter* 291, July (1986): 79.

[14] Pierre Fleury to Professor E. Hutchisson, February 5, 1959, and Elmer Hutchisson to Pierre Fleury, January 8, 1959, series E1 "Larkin Kerwin's and Pierre Fleury's correspondence," vol. 3, folder 24 "Commission on publications, also report to the President of ICSU 1960," IUPAP Quebec.

[15] Josep Simon, "The Transnational Physical Science Study Committee: The Evolving Nation in the World of Science and Education (1945–1975)," in *How Knowledge Moves: Writing the Transnational History of Science and Technology*, ed. John Krige (Chicago: University of Chicago Press, 2019), 308–42; Archie K. Lacey, "'Continental Classroom' and the Small Science Department," *Science Education* 43, no. 5 (1959): 394–8; Raymond J. Seeger, "Progress Report on Physics in Engineering Education," *American Journal of Physics* 24, no. 2 (1956): 70–7.

[16] See Rudolph, *Scientists in the Classroom*.

methods of student and teacher assessment as a measure of pedagogical effectiveness, and promote the "exchange of information and ideas" through for instance international conferences.[17] Contemporaries noted the 1960 conference recommendations of "a major improvement in the degree of professionalism and the working conditions of physics teachers and a closer relationship between universities and secondary schools in the area of physics education."[18]

A month after the Paris conference, the IUPAP General Assembly held in Ottawa confirmed the formation of the Commission on Physics Education, chaired by Brown, with Clarke as Secretary, and members Pierre Fleury (France), Antonius M. J. F. Michels (Netherlands), Daniele Sette (Italy), Jayme Tiomno (Brazil), and Vasily S. Fursov (USSR). Correspondent members were Mahmoud A. El Sherbiny (Egypt) and Miloslav Valouch (Czechoslovakia).[19] Tiomno would be the prime mover of the second IUPAP conference which, even before the Paris conference, IUPAP's Secretary General was taking for granted would be in Rio.[20]

With support from the new commission, Kelly coordinated the publication of *A Survey of the Teaching of Physics at Universities*, with data from Czechoslovakia, Germany, France, Great Britain, the USA, and the USSR; and he also produced a specific report only for the USA.[21] In 1966, Kelly substituted Clarke as Secretary of the commission. He had by then great experience in an analogous role at the AIP.

Following the Paris conference, the PSSC—an MIT project—organized a workshop to introduce its pedagogical materials in Europe. The OEEC sponsored both IUPAP's conference and the PSSC workshop. Conversations between the PSSC and OEEC officers illustrate the robust connections of science pedagogy with disciplinary knowledge and the international politics of science: knowledge content or subject matter were closely linked with pedagogical techniques, making both aspects hardly separable. This matches Shulman's concept of *pedagogical content knowledge* characterizing *signature pedagogies* that I use in the next sections.[22] Moreover, an integrated transformation of physics and its pedagogy would only be attained through focused

[17] IUPAP, "International Conference on Physics Education. Resolutions," in Brown and Clarke, *Proceedings*, on 1–3.

[18] Anthony P. French, "The International Commission on Physics Education," *Contemporary Physics* 21, no. 4 (1980): 331–44, on 335.

[19] Pierre Fleury, ed., *L'Union Internationale de Physique Pure et Appliquée. État au 1er janvier 1961. Procès-verbal de la dixième Assemblée Générale (1960). Janvier 1961. U.I.P. 8* (Paris: Secrétariat. IUPAP, 1961), 12, 28, IUPAP Gothenburg, series B2aa "General Reports," vol. 1.

[20] Cesar Lattes to Pierre Fleury, March 1, 1960, and Pierre Fleury to César Lattes, July 21, 1960, series E6 "Correspondence with Liaison Members," vol. 2, folder 6 "Brazil (Brasilien) 1950–1999," IUPAP Gothenburg.

[21] William C. Kelly, coord., *A Survey of the Teaching of Physics at Universities* (Paris: UNESCO, 1966); and *Survey of Education in Physics in Universities of the United States* (New York: American Institute of Physics, 1964).

[22] This concept encapsulates the relationship between how a school discipline is taught and what is taught: what teachers know about their practice (pedagogical knowledge) and what they know about what they teach (subject matter or disciplinary knowledge). Pamela L. Grossman, Suzzane M. Wilson, and Lee S. Shulman, "Teachers of Substance: Subject Matter Knowledge for Teaching," in *Knowledge Base for the Beginning Teacher*, ed. Maynard C. Reynolds (Oxford: Pergamon Press, 1989), 23–36; Lee S. Shulman, "Paradigms and Research Programs in the Study of Teaching: A Contemporary Perspective," in *Handbook of Research in Teaching*, ed. Merlin C. Wittrock (New York: Macmillan, 3rd edn, 1986), 3–36.

and intensive practice. Finally, US hegemony in physics pedagogy required hard work through sustained negotiations by individuals, professional societies, and national organizations in the framework of international meetings.[23]

The workshop was held at the Cavendish Laboratory (UK), one year after the Paris conference, and attended by teachers from fourteen European countries. The OEEC group of experts discussed the PSSC proposal, and Clarke managed all the practical arrangements.[24] While the OEEC desired a diverse program (in the mold of IUPAP's conference) displaying its own initiatives and the views of European physicists and physics teachers, the PSSC strove for an exclusive focus on PSSC material and staff. The PSSC perspective prevailed and IUPAP's participation was null (Clarke attended only as an OEEC representative).[25]

IUPAP's second conference on physics education (Rio de Janeiro, 1963) was similar to the first one in the number of participant countries (twenty-nine) and attendants (more than 150). It was hosted by the *Centro Brasileiro de Pesquisas Físicas* (CBPF), the *Centro Latino Americano de Física*, UNESCO, Brazil's Ministry of Education and Culture, and its national research council, and coordinated with the OAS—which a week earlier held an analogous (but inter-American) conference at the same place. The only change in the Commission on Physics Education was the substitution of Fursov by A. S. Akhmatov (Moscow's Institute of Machines and Instruments).

There was a large representation from Brazil, more than eighty delegates (around half of the conference participants) from across the country, but especially from Rio and São Paulo. Because of the OAS conference, there were representatives from all American countries, except Cuba, Haiti, Jamaica, and a few small Caribbean states.[26] After Brazil, the largest delegations were from Argentina and Chile, followed by Peru, Mexico, and Venezuela—each of these quantitatively comparable to the US delegation, which however included additional representatives from the OAS, the AIP, the NSF, the Ford Foundation, the US Regional Science Office for Latin America, and the embassy. Brazil, Argentina, Venezuela, France and the Netherlands sent representatives of their ministries of education. The only European delegates represented Czechoslovakia, France, Italy, the Netherlands, Spain, Sweden, and the UK. This time, Canada, South Africa, and Japan sent representatives, but not Australia. Morocco had a delegate for the first time, but there were no others from the Arab world.

The *Centro Latinoamericano de Física* (co-host of the conference), had been established in the CBPF's premises in March 1962, in coordination with the Brazilian Ministry of Foreign Affairs and fifteen Latin American countries, following a

[23] Francis Friedman to Robert Ganeff, January 25, 1961, PSSC Records, series MC626, box 12, folder "Correspondence 1961–1962," the MIT Archives.

[24] Robert Ganeff to Professor Friedman, January 13 1961, PSSC Records, series MC626, box 12, folder "Correspondence 1961–1962."

[25] Robert Ganeff to Professor Friedman, January 25, 1961, PSSC Records, series MC626, box 12, folder "Correspondence 1961–1962"; Friedman to Ganeff. January 25, 1961; James Ronald Gass to Uri Haber-Schaim, December 12, 1960 and Uri Haber-Schaim to J. R. Gass, January 27, 1961, PSSC Records, series MC626, box 12, folder "Correspondence 1961–1962."

[26] IUPAP Latin American members were Mexico (1925), Brazil (1951), and Argentina (1951). Bolivia joined in 1963, Cuba in 1969.

UNESCO resolution. It intended to further research and training in physics with a focus on technical advice, large-scale problems, and Latin American professionals.[27]

Pedagogical Content Knowledge in IUPAP's Paris Conference, 1960

In his opening address, René Maheu, UNESCO's acting director general considered that "it is obviously an impossibility to draw up a universal textbook for the teaching of physics, because even though physics is universal, the conditions of teaching of physics most certainly are not, and the degree of progress in the various countries varies considerably."[28]

The conference resolutions considered physics as a "unique interplay of logical and experimental disciplines," and the study of its subject matter and "physicist's methods of acquiring and evaluating knowledge" as a must for all school students. There was a critical need of "specialized teachers who can keep abreast of developments in a rapidly growing subject." A main goal was "to improve both the efficiency and the attractiveness of physics teaching as a profession" and to demarcate the physics teacher profession: in secondary and university education, "physics should be taught by physicists, that is, by men and women who have received a professional training in physics." This might seem obvious, but it diverged with most school contexts (with a diversity of training profiles, in the sciences, engineering, and teaching). It aired the university physicist's anxiety for bringing the school physics teacher to the university ways of conceiving and practicing specialized knowledge. Improving the salary and status of physics teachers was only secondary to providing them with the conditions for performing experimental work (time, apparatus, training). It was thus that teachers would "feel that they form an integral part of the development of physical knowledge."[29] Clearly, a top-down approach, in which university physicists would enlighten schoolteachers with their knowledge and practice. The conference itself was a perfect illustration of this view since school physicists were practically absent.[30]

The OEEC report stressed the development of a new way of teaching physics in general education (subsequently the topic of the Rio conference). Clarke emphasized the need for distinguishing science from technology and appreciating the cultural value of science for all students. He suggested changing the traditional sequence of physics courses (governed by mechanics), rounding the concept of atoms and molecules, and a balanced combination of theory and experiment.[31]

The conference discussion of examinations (and their evaluative vs. selective function) contained empirical experience and some reflection, but a dearth of pedagogical methodology (from educational psychology and science education research).[32] One

[27] Gabriel Fialho to IUPAP President, March 18, 1962, series E6 "Correspondence with Liaison Members," vol. 2, folder 6 "Brazil (Brasilien) 1950–1999," IUPAP Gothenburg.

[28] René Maheu, "Greetings from UNESCO," in Brown and Clarke, *Proceedings*, on xv–xvi.

[29] IUPAP, "International Conference on Physics Education. Resolutions," on 3.

[30] The only physicists with experience in school contexts were arguably Marcel Eurin, Antonius Michels, Ruud L. Krans, and Malcolm R. Gavin.

[31] Norman Clarke, "Physics as a Part of General Education," in Brown and Clarke, *Proceedings*, 12–22.

[32] "Examinations in Physics," in Brown and Clarke, *Proceedings*, 23–33.

of the presenters considered that what universities produced was "training in an intellectual discipline." The physics professional was only made subsequently through practice[33]—something that applies to every profession.

US initiatives were given prominence. In a monograph session early in the conference, Zacharias presented the PSSC. He stressed the requirement for physics students to "acquire insight into the scientific process, not merely a catalogue of scientific and technological facts." The PSSC advocated for selective subject matter, general connective principles across classroom materials, and a set of "interrelated learning aids," a combination of "exploration in the laboratory, analysis in the text, and illustration by means of films" (also able to substitute complex or expensive experimental sets). The PSSC package was on the market just one month after the Paris conference, and early this year, they were already planning to export it.[34]

The working program of the conference closed after seven days, with a monograph session on film and television, as a cutting-edge means of physics teaching dominated by a US initiative. White discussed his involvement in televised physics courses, and the capacity of television for large-scale audiences, to strengthen teacher authority, multiply pedagogical clarity, and focus student attention. Television and film were the modern replacement of the traditional textbook. Kelly (as AAPT representative) emphasized the capacity of films for focused classroom practice introducing research physicists and laboratories to school students. Discussants expressed, however, concerns about television and film substituting the teacher's practice, their teaching efficiency, cumbersome technical handling, and pedagogical limitations (unidirectional communication). The OEEC also informed of its projects in that field.[35]

Between MIT's *Physical Science Study Committee* and Berkeley's *Continental Classroom*, a series of monograph sessions staged a more diverse range of national delegate interventions, across a conference week devoted to finding the soul of physics inside its fundamental educational problems.

"The Place of Laboratory Work in Teaching Physics," was tackled by Malcolm Gavin (University College of North Wales), experienced both in school teaching and industrial physics. For him, laboratory teaching allowed acquiring practical skills and methods, and introducing students into the physics way of thinking. Aspects to consider were the role of lecture demonstrations vs. laboratory experiments conducted by the teacher or by students themselves, measurement errors and recreation of real situations, and experiment interpretation. The selection of experiments for a non-specialist course depended on various pedagogical priorities: subject matter, problem experiments framed in school research projects, or relative availability. It was relevant to consider how laboratories could be fruitfully used with large student numbers. A historical approach (through classic experiments) could be motivational and generally useful.

[33] G. K. T. Conn, "The Selection of Students," in Brown and Clarke, *Proceedings*, 34–9.

[34] Jerrold R. Zacharias, "The Work of the American Physical Science Study Committee," in Brown and Clarke, *Proceedings*, 40–53, on 41; Simon, "The Transnational," 317–26.

[35] "The Use of Television and Films in Physics Teaching," in Brown and Clarke, *Proceedings*, 100–21.

The question of science equipment supplies in countries with limited resources (e.g., Latin American countries) was raised by Hilliard Roderick and Nahum Joel (representing UNESCO). It was necessary to design experimental work with simple apparatus, for instance using domestic appliances. In this context, Kelly advertised the work of the AAPT's Committee on Apparatus, which had established programs with commercial companies and circulated apparatus designs amongst US universities. An exhibition of physics teaching apparatus was available throughout the conference, dominated by French and British university laboratories together with US, British, and West German companies, and one or two stands by Swedish and Swiss instrument makers.[36]

Discussions on subject matter, methods, and materials flowed in several streams debating the training and profiling of physicists. In a monograph session, Boris Rosen (Université de Liège), valued particularly the professional task of the teacher: "at a higher level of teaching, ... research and teaching inevitably go together, and, while it is agreed that mediocre teachers can do excellent research, the opposite is difficult to conceive."[37] The field was characterized by lack of communication between schools and universities. It was thus necessary to develop in-service university training opportunities for teachers and research groups in order to integrate high-school and university professionals. The OEEC report followed analogous lines and displayed the tension between educational interest (the "educators" or "educationalists") and specialized interest ("the physicists").[38]

The dichotomy between acquiring new physical knowledge vs. new pedagogical techniques was also explicit among professional teacher trainers. Ruud Krans (*Universiteit Utrecht*) suggested that after choosing the teaching profession late in their physics degrees, the non-specialized nature of most pedagogical training deterred many students to follow this career. While Krans emphasized the urge of a special physics didactics, Hans Staub (a Swiss nuclear physicist) stressed that "the training of a physicist should be exactly the same whether he goes into research or he goes into teaching. We simply want to educate him to be a good scientist." For him, the importance of pedagogical courses was overrated. His view that "[a] good physics teacher is simply a good teacher" was shared by many conference attendants. He also claimed that "a good teacher, is just born, we cannot educate him to be one."[39]

The epistemological fragility of these firm beliefs among university physicists is evidenced by simply substituting "physicist" for "teacher" in the last quotation, and asking: is formal training required or not for the making of physics researchers, professors and teachers?

The following conference sessions intended to define physics by demarcating it from neighboring fields. A major theme was physics for engineers, chemists and other science students. Pierre Aigrain, a French solid state physicist, considered that mathematics played the essential role (distinguishing physicists from chemists). He reckoned that "the distinction between engineer and physicist is disappearing," and

[36] "The Place of Laboratory Work in Physics Teaching," Brown and Clarke, *Proceedings*, 54–72.
[37] Boris Rosen, "The Training of Teachers," in Brown and Clarke, *Proceedings*, 73–87, on 74.
[38] In the following paragraphs, I analyze the discussion developed in the session opened by Rosen.
[39] Rosen, "The Training of Teachers," on 80.

engineers were more needed in growing economies (e.g., those of developing countries). The physics curriculum should be the same for engineers and physicists, but the former should periodically take refresher courses given by the latter.[40]

Conversely, C. Guy Suits (from General Electric) expressed the great interest of industry for physicists, but the required adaptation of their university training to industrial research.[41] This view was shared by conference attendants affiliated to engineering schools—especially the Polish, Finnish, Soviet, and German delegates: engineering required different types of physics courses. In a lengthy report, the Soviet delegate characterized "technical or engineering physics" and described how it was organized in the USSR, with an emphasis on avoiding segmentation by physics subdisciplines.[42]

While the conference ended with a session looking at the (US) present and future of film and television physics teaching, its organizers preferred to end the published proceedings with a discussion on "The Impact of Organizations of Professional Physicists," based on pre-circulated papers. Societies were the most powerful organizations acting on the demarcation of the discipline and regulation of the profession. The session was strongly driven by Anglo-US perspectives, with contributions by Kelly (AIP), Leonard Olsen (AAPT), and Clarke ((British) Institute of Physics).

Kelly informed once again on the wide range of activities developed by the AIP. Olsen emphasized the relation between teachers' competence and command of subject matter. The AIP's and the AAPT's projects were developed by university research physicists who had recently become interested in educational reforms. According to Clarke, a professional society was responsible for advancing the subject it represented by defining professional competence. It was constituted by a restricted number of (competent) members responsible for advancing the interests of the discipline. As Clarke revealed, the Institute of Physics' membership included university professors, research students, and directors of industrial firms, but not schoolteachers.[43]

Clarke's expression of the mission of professional and disciplinary societies (national or international) is naive. The professional aim of advancing physics as a discipline is particularly visible across IUPAP's Paris proceedings. At the same time, the conference represented quite exclusively the professional interests of university physicists and their particular vision of the subject and its teaching. Another relevant question is to what extent the conference favored the interests of particular national communities of physicists (e.g., US, British, and French delegations)?

The Paris and Rio conference proceedings were also full of prejudiced and patronizing views on physics in countries beyond Europe and the USA. In one of the Paris opening addresses, Yves Rocard (École Normale Supérieure) used a deterministic geo-climatic approach (as old as the French Enlightenment),[44] to characterize scientific progress in different areas of the world. Moreover, he considered

[40] Pierre Agrain, "The Teaching of Physics to Engineers, Chemists, and Other Science Students," in Brown and Clarke, *Proceedings*, 122–7.
[41] C. Guy Suits, "The Postgraduate Training of Physicists," Brown and Clarke, *Proceedings*, 88–95.
[42] Brown and Clarke, *Proceedings*, 122–40, esp. 124.
[43] "The Impact of Organizations of Professional Physicists," in Brown and Clarke, *Proceedings*, 149–64.
[44] See David Arnold, *The Problem of Nature: Environment, Culture and European Expansion* (Oxford: Blackwell, 1996).

that in underdeveloped countries—that he characterized as places "without airplanes, without motor cars, and without radios"—experimental physics teaching would be increasingly required to introduce school children to modern civilization.[45] In developed countries, this might be redundant since pupils would easily find a natural familiarization with scientific and technical cultures at home.

This argument would be mentioned again in the Rio conference by one of the Brazilian delegates (engineer Paulo Leite), despite the rather advanced early development of aviation, automobility, and radio in Latin America.[46] Moreover, Brazil had organized its first national course for the improvement of physics teaching in secondary education a decade before IUPAP's 1963 conference. The second edition of this course (1955) was held at the Technological Institute of Aeronautics, in São José dos Campos—a town immersed in the process of becoming a major technological cluster. The meeting proceedings displayed premises with well-catered laboratories.[47] This level of equipment would not apply to most educational institutions across the country. Still, Brazil had a large network of physics and engineering institutions already performing critical physics research and teaching.[48]

IUPAP's 1957 General Assembly had raised the question of helping some countries to develop physics further. The proceedings' French version referred to "physics knowledge and research;"[49] the English version, to "physics teaching and research"—thus emphasizing the role of teaching in the making of disciplinary knowledge.[50] Debates referred to "countries where this seems desirable;" the resolutions termed them as "*under-developed* countries" (note the italics suggesting a novel and not yet standardized linguistic use). It was agreed to channel this aim through UNESCO and that it could only succeed when some capability was already in place.[51] The Eleventh General Assembly of the International Council of Scientific Unions (ICSU) (Bombay, 1966) established a Committee on Science and Technology in Developing Countries.[52] In the 1970s, IUPAP's assemblies favored the use of the binomial "developing"/"developed" (country). We thus know that a country might become "developed" by developing its physics more. However, beyond a common—technodeterministic, lineal, and asocial—use of the term "development," there was no real

[45] Rocard, "Opening Address," in Brown and Clarke, *Proceedings*, 5–6, on 6.

[46] Araceli Tinarejo and J. Brian Freeman, eds., *Technology and Culture in Twentieth-Century Mexico* (Tuscaloosa, AL: The University of Alabama Press, 2013); David Pretel and Helge Wendt, eds., "Special Issue: History of Technology in Latin America," *History of Technology* 34 (2019): 1–256.

[47] IBECC, *II Curso de aperfeiçoamento para professores de física do ensino secundário* (São Paulo: Instituto Brasileiro de Educação, Ciência e Cultura, 1955).

[48] Simon Schwartzman, *A Space for Science: The Development of the Scientific Community in Brazil* (Philadelphia: The Pennsylvania State University Press, 1991), 199–214; Simon, "The Transnational."

[49] In French, "*connaissances*" (not generic, but plural).

[50] More on this in Simon, "Writing the Discipline," and John L. Heilbron, "History of Science or History of Learning," *Berichte zur Wissenschaftsgeschichte* 42, nos. 2–3 (2019): 200–19.

[51] IUPAP. *État au 1er janvier 1958. Procès-verbal de la neuvième Assemblée Générale (1957)*, 24 (article d) and 28 (Résolution 2), and *Position at 1 January 1958. Report of the Ninth General Assembly (1957)*, 23 (article d) and 27 (Resolution 2), series B2aa, vol. 1 "General Reports," 1923–1966, IUPAP Gothenburg.

[52] Frank Greenaway, *Science International: A History of the International Council of Scientific Unions* (Cambridge: Cambridge University Press, 1996), 123 and 133.

discussion at IUPAP's conferences on the complex, multi-sided, and contested aspects of the rhetoric and actions of "development."[53]

The week before the IUPAP conference, the OAS conference had displayed a full picture of the physics profession in Latin America. Kelly and Rogers gave papers at that conference too, and Brown was in its advising committee, although he might not have attended. All pre-circulated papers were written in Spanish and Portuguese except those by Kelly and Rogers; none of them were cited in the proceedings of IUPAP's Rio conference. Many US and European participants in IUPAP's conferences evidenced they had a biased and misinformed view of Brazil and Latin America, analogous to that of an "empty continent" held by European colonizers.[54]

Pedagogical Content Knowledge in IUPAP's Rio de Janeiro Conference, 1963

In their preface to the 1963 conference proceedings, Brown and Clarke (with the acquiescence of Tiomno as third signing author) justified the selection of Rio "because of relatively easy accessibility from other Latin American countries" and "the attractiveness of the city itself." In parallel, they stressed that "the less developed countries of the world are obviously unable to offer such clear advantages" as the "virtually unlimited amount of experienced assistance and advice," research laboratories, scientific apparatus manufacturers, and other scientific resources available in Europe and the USA. According to them, "import formalities and restrictions made it impossible to have a truly international exhibition of equipment, and no exhibition of books could be arranged" at Rio.[55] This was inaccurate, and a sign of the biased politics of the conference—conceived as a platform for acculturating Latin American research and teaching physicists in the US and European physicists' gospel. Nonetheless, in Rio, there was an exhibition of teaching apparatus from Brazil (Instituto Brasileiro de de Educação, Cinência e Cultura, IBECC), the USA (AAPT), and Sweden.

The conceptual organization of the meeting was run by Brown and Clarke as representatives of the interests of US and British/European university physicists. Only the practical aspects were handed to the Brazilian hosts, and the availability in Brazil of scientific facilities, research teams, specialized libraries and laboratories, and science teaching innovation projects were considered very partially. Moreover, while European and especially US physicists had indeed superior material means, they analogously struggled with critical needs of educational reform and science teaching

[53] See Ricardo Bielschowsky, (org.), *Cincuenta años de pensamiento en la CEPAL: Textos seleccionados* (Santiago: CEPAL-Fondo de Cultura Económica, 1998); Arturo Escobar, *Encountering Development: The Making and Unmaking of the Third World* (Princeton: Princeton University Press, 1998).

[54] Unfortunately, the scientific, technological and educational developments of the 1950s were truncated by the military coup d'état in Brazil, nine months after IUPAP's conference, which forced relevant physicists (e.g., Tiomno) and educationists (e.g., Raw) to go into exile. IUPAP's conference proceedings, had no mention to this fact. On the "empty continent," see Eduardo Subirats, *El continente vacío: La conquista del Nuevo Mundo y la conciencia moderna* (México DF: Siglo XXI, 1994).

[55] Sanborn C. Brown, Norman Clarke, and Jayme Tiomno, "Preface," in *Why Teach Physics? Based on Discussions at the International Conference in General Education* (USA: IUPAP-The MIT Press, 1964), v–viii, on vi–vii.

apparatus supply.[56] The fourteen talks at the Rio conference were all—except two—by European and US physicists. There was a greater effort to include members of most delegations in the organized discussions of the papers.

In his opening address, Tiomno delved into the then common discourse of scientific and technological progress for development, and considered that "[i]t is a propitious sign for humanity as a whole that the cold war between the world's two greatest powers is being replaced by technological and educational competition."[57] A decade earlier, he had co-authored a diagnostic paper on school physics teaching in Brazil, and a translation of a 1940s textbook by Oswald Blackwood, revised in the mid-1950s with the help of Kelly.[58] The resolutions of the First Inter-American Conference on Physics Education, appended to Tiomno's paper, were chiefly a refined version of the Paris conference resolutions.[59]

In his presentation, entitled "Observations on the Teaching of Physics in Developing Countries," Paulo G. de P. Leite underlined the excessive emphasis in Brazilian school and university teaching on "description of facts and apparatus" and "formal development of equations," against a more essential understanding of "physical phenomena and concepts," and the ability to perform experimental teamwork. According to him, these flaws were connected to lack of training in educational psychology and a curriculum oriented towards engineering school entrance examinations.[60] Leite described, in fact, a state of affairs characterizing any of the countries attending IUPAP's conferences—which, for instance, had triggered the US school science reform in the mid-1950s. The same emphasis was given by Brown in his address "Cultural Values in Science Teaching," but he referred more restrictively to the conceptual structure of physics—much in the PSSC mold.[61]

In the discussion of Brown's rather general and clumsy paper, a tension emerged between a number of physicists with different profiles and commitments across pedagogy, management, and research. Picking on a general reference made by Brown, Zacharias criticized him by stating that the suggestion that "any subject can be taught effectively in an intellectually honest form to any child at any stage of development" was only applicable to mathematics. This occasion was picked up by Richard Feynman—who joined the US delegation while a visiting physicist at the CBPF—to jump into the discussion by asking "whether anyone yet knew enough about teaching physics to nonspecialists to justify discussing the subject on an international basis." Oppositely, Clarke and Sette reacted with arguments and data in defense of Brown.[62]

[56] Simon, "The Transnational."
[57] Jayme Tiomno, "Science Education in the Contemporary World," in Brown, Clarke, and Tiomno, *Why Teach Physics?*, 7–10, on 9.
[58] Jayme Tiomno and José Leite Lopes, "O ensino da física nos cursos secundários," *Ciência e Cultura* 5, no. 1 (1953): 45–7; Ildeu de Castro Moreira, "Feynman e suas conferências sobre o ensino de física no Brasil," *Revista Brasileira de Ensino de Física* 40, no. 4 (2018): e4203-1-e4203-7; Ostwald H. Blackwood, Wilmer B. Herron, and William C. Kelly, *Física na Escola Secundária* (Rio de Janeiro: Fundo de Cultura, 1958).
[59] Tiomno, "Science Education in the Contemporary World."
[60] Paulo G. de P. Leite, "Observations on the Teaching of Physics in Developing Countries," in Brown, Clarke, and Tiomno, *Why Teach Physics?*, 11–12.
[61] Sanborn Brown, "Cultural Values in Science Teaching," in Brown, Clarke, and Tiomno, *Why Teach Physics?*, 13–19.
[62] Ibid., 18–19.

Feynman's intervention was particularly insolent, but no more so than the keynote address he had given at the OAS conference, pompously entitled "The Problem of Teaching Physics in Latin America."[63]

This tension also appeared in the defense by practicing physicists of pedagogical approaches resting on different epistemological and socio-political foundations. Feynman contended that there was an essential epistemological difference between science and the humanities and mixing "the two together at too early an age is a danger and a destroyer of the true cultural value of science." Science was exceptionally characterized by "clear thinking, a knowledge of one's hypothesis and constant reference to experiment which was a guide to truth that was independent of authority or of opinion," thus, it "should be taught in the purest way possible."[64] This has been a typical perspective of many research scientists.[65] It was nonetheless in stark contrast with the views of Gerald Holton, as presented in an inaugural talk in Rio. Holton considered that,

> Indeed, "pure" physics is an invention that exists only in the old-fashioned classroom. As soon as a real problem in physics, or any other field, is grasped, it appears that there hang from it connections to a number of expected and unexpected problems in fields that, by habit, we make our students think of as "belonging" to other professions.[66]

The challenge of developing a physics course for non-physicists offered the opportunity of rebuilding physics pedagogy on more solid foundations and demonstrating the relevance of physics in general culture. He proposed a "connective approach to the teaching of physics" based on the articulation of a "constellation" of related disciplines: A new picture would emerge in any student, of "physics as a member of a constellation of concerns, so different from the usual, artificial picture of physics as the isolated and stern subject that has nothing to contribute to anything but more physics."[67] Holton did not only seek greater pedagogical efficiency, but also a civic ethos applied through schooling to the "university" (as scholarly community) and the USA (as a diverse society). Other conference delegates such as Xavier Roser and Antonius Michels advocated for a similar ethos.

Like Holton, and in contrast with Feynman, Eric Rogers considered too that "[w]e must not hope to train our nonscientists to be scientific, with a full knowledge and practice of some mysterious ideal 'scientific method' such as that artificial scheme set forth by Sir Francis Bacon, and still preached by philosophers but not practiced by real physicists!"[68] Rogers was the author of *Physics for the Inquiring Mind* (1960)

[63] Richard Feynman, "The Problem of Teaching Physics in Latin America," *Engineering and Science* 27, no. 2 (1963): 21–30; Moreira, "Feynman," e4203-2– e4203-3.
[64] Brown, Clarke, and Tiomno, *Why Teach Physics?*, on 18.
[65] David Locke, "The Putative Purity of Science," in *Science as Writing* (New Haven: Yale University Press, 1992), 133–66.
[66] Gerald Holton, "The Goals for Science Teaching," in Brown, Clarke, and Tiomno, *Why Teach Physics?*, 27–44, on 38.
[67] Holton, "The Goals for Science Teaching," on 39–41.
[68] Eric M. Rogers, "Teaching Physics for Understanding in General Education," in Brown, Clarke, and Tiomno, *Why Teach Physics?*, 51–60, on 52.

and one of the (British) Nuffield Science Teaching Project coordinators. He emphasized a selective subject choice on which to get in depth and build clear and durable understanding. However, he admitted many possible choices, as long as the selected subjects allowed linkages across physics. He also wanted students to build their own guided classroom and laboratory research with simple equipment (available in the domestic context). In his update on the PSSC, Zacharias noted the connections with Rogers' approach and expounded the expanding use of the PSSC course in the USA and adaptation in several European, Latin American and Asian countries.[69]

Isaias Raw emphasized the need to develop elementary science teaching in relation with daily life, through experimental teaching with the aid of cheap scientific kits, television programs and science fairs. Raw had started his work in the 1940s and subsequently had a major role in UNESCO's Pilot Physics course and the Brazilian PSSC's adaptation. He had also constituted a team with its own educational projects through UNESCO's IBECC, the Universidade de São Paulo, national and international funding, and the attempt to establish a teaching equipment company, analogously to the scheme developed by PSSC.[70]

Connectedly, Albert Baez, head of UNESCO's Division of Science Teaching, explained their Pilot Physics course: UNESCO developed a large number of actions and served more than a hundred member states. However, its budget was typically the same as that of the PSSC for just one country and one science. Its physics project used programmed instruction, low-cost experiments, film, and television. It relied on the IBECC's cumulated experience in the production of inexpensive science teaching equipment, and teacher training. The project had the potential to congregate teachers and university lecturers from across Latin America.[71]

In his presentation, Daniele Sette informed about other pilot courses, developed by the OECD in the Scandinavian countries, Spain, Italy, and Yugoslavia, using PSSC materials and their adaptations. Amongst these, a project in Sicily with mobile units for physics teaching with experiments, in places with little access to this expertise and equipment.[72] Christina A. M. Michels-Veraart (*Universiteit van Amsterdam*) focused on educational psychology, the relevance of understanding how children build their notions of causality, and how physics could contribute to the development of their interest in the world around them.[73]

John L. Lewis explained that the UK had not adopted the PSSC, due to having a different physics teaching tradition, enough pedagogical expertise, and a better-suited course by the Nuffield Foundation. He stressed that like the PSSC, the Nuffield course included atomic physics—a novel teaching subject able to catch student's attention, promoting critical thinking, integrating historical and philosophical perspectives,

[69] Jerrold R. Zacharias, "Curriculum Reform in the U.S.A.," in Brown, Clarke, and Tiomno, *Why Teach Physics?*, 66–70.

[70] Isaias Raw, "The Brazilian Institute of Education, Science and Culture (IBECC)," in Brown, Clarke, and Tiomno, *Why Teach Physics?*, 61–4; Simon, "The Transnational," 321–23.

[71] Albert Baez, "UNESCO and Science Teaching," in Brown, Clarke, and Tiomno, *Why Teach Physics?*, 75–7.

[72] Daniele Sette, "Some European Developments in Science Teaching," in Brown, Clarke, and Tiomno, *Why Teach Physics?*, 64–6.

[73] Christina A. M. Michels-Veraart, "Science in Elementary and Secondary Education," in Brown, Clarke, and Tiomno, *Why Teach Physics?*, 45–50.

connecting with chemistry, and allowing a good amount of experimental work. Nuffield had also produced some films, but favored classroom experiments and had collaborated with British instrument makers to produce low-cost teaching apparatus. The project explicitly engaged schools and schoolteachers (such as Lewis himself).[74] Analogously, Swedish delegates advocated for a pedagogical approach focused on demonstrative experiments with the aid of simple and inexpensive designs. Like the British, they had been able to involve local instrument makers in a Swedish line of teaching experiments and apparatus, displayed at the conference.[75]

The closing session of the conference, chaired by Brown, recommended educationists and governments all over the world to "be acquainted with the important work in this field currently being done in Europe, the U.S.A., and elsewhere," and adapting or using it according to their needs. As the conference theme was "physics in general education," and since only "a very small proportion of the population of any country will be professional physicists," its focus was to make physics "a working tool in the life of the educated man." According to Brown, it was therefore agreed that the stress should be on the "conceptual framework of physics, ... and not merely individual facts" (although this was actually not a simple and inconsequential pedagogical choice). Physics should be taught across the school curriculum and start at an early age. Depth should be favored against breadth, but a core of the more distinctive topics should be given to all students, even to those not expecting to become "professional physicists." Examples of new pedagogical schemes discussed at the conference were the PSSC, Nuffield (for Brown "in a way similar to PSSC but designed to cover several years"), UNESCO's pilot project (developed in Brazil), and the project of Mobile Units in Sicily (useful in countries with scarce teaching resources and trained staff). Films and their role in physics education took a large part of the conference discussions. They were valuable for several reasons, including that of substituting lack of apparatus or teachers trained to perform experimental work, but they should be designed adequately to fit a certain teaching philosophy.

We know that the participants designated for the discussion of Brown's closing summary were Zacharias, Georges Boutry (France), A. Bueno (Peru), Juan Herkrath (Colombia), João Jesus de Salles Pupo (Brazil), and IUPAP's Secretary General Pierre Fleury. Raw was Secretary of the session chaired by Brown. However, the proceedings are silent about any closing discussions and transferred Brown's summary to the opening pages of the publication.[76] Although the relative prominence of the PSSC in the Rio conference was less explicit than in the Paris program, it is noteworthy that Zacharias was the first speaker in the list of discussants. Brown's summary shows both explicitly and implicitly the penetration of the PSSC (on questions such as subject matter, pedagogical method, teaching aids, and professional politics). This was also clear across the conference presentations, in which the MIT's project was referenced and recommended more than any other.

[74] John Lewis, "The Place of Atomic Physics in General Education," in Brown, Clarke, and Tiomno, *Why Teach Physics?*, 70–5.

[75] Erik Ingelstam and Karl Gustav Friskopp, "Principles of Classroom Demonstrations and Laboratory Work," in Brown, Clarke, and Tiomno, *Why Teach Physics?*, 79–83.

[76] Brown, Clarke, and Tiomno, *Why Teach Physics?*, 1–2 and xxiii–xxv.

Conclusion

The signature pedagogy of physics, presented at IUPAP's early conferences on physics education, was characterized by a focus on laboratory teaching, the introduction of atomic physics in the school curriculum, and the segmentation of the physics subject matter, the provision of teaching apparatus, and the design of controlled pedagogical experiments. Furthermore, the development of techniques to cope with a prospective increase in university enrolments, and the desire of university physicists to control professional certification and university training in physics across the sciences and engineering were also major features.

The conferences display a variety of views on the disciplinary characterization of the knowledge base of physics and how to put it into practice—although the experimental approach was arguably gaining momentum. Laboratory teaching equipment had a central role in any project of pedagogical reform. Most proposals advocated for low-cost and simple equipment produced in university or school workshops, or the appropriation of domestic technologies. However, the projects with a more powerful repercussion, such as the PSSC, established companies to commercialize self-contained pedagogical packages. Educational projects had still a relevant dependence on instrument making firms or adopted their strategies.

The process of making the physics profession through educational reform was full of tensions between physicists and engineers, science teachers, educationists, and policy managers, and between US physicists and other professionals in Europe and Latin America. A top-down approach characterized the ethos of IUPAP's earliest conferences in the relationship between university physicists and physics teachers, and between European/US physicists and professionals from other countries (in Latin America, but also southern and eastern Europe). However, the time between the two conferences saw the burgeoning of a larger number of projects, and some more germane to the professional and disciplinary concerns of schoolteachers and general citizens.

Feynman's participation in IUPAP's Rio conference was marginal but illustrative. He was just one of many discussants in a conference session. Taken literally, his intervention could make us think he was just passing by—but, actually, it was not casual. He had had a relevant role as a keynote speaker in the OAS conference. His address was, in fact, a recycling of a talk given a decade earlier during a sabbatical year spent in Rio. It basically expressed personal opinions and provided no evidence (national, regional, comparative data), or conceded it could be wise to ask conference participants (who had pre-circulated detailed national reports on physics teaching in Latin America). He had some anecdotic university teaching experience in Brazil and could echo some of his Brazilian colleagues' comments. He was undoubtedly the author of the forthcoming *Feynman Lectures in Physics* (1964) based on a course given at Caltech between the years of the two IUPAP conferences. However, he did not have any substantial teaching experience in Latin America.

In spite of this, some of Feynman's remarks were relevant and surely applicable to Brazil. However, they were analogous to the problems pinpointed in most countries in this period, which had triggered—more or less simultaneously—movements for science education reform in the USA, Europe, and Latin America. Feynman's pretension of tutoring his colleagues from across the continent is ludicrous, but illustrative of the international epistemic politics of physics teaching and "development" in that period. Due to the professional prestige of the foreign visitor and his powerful nationality, he might still have been useful to the cause of Brazilian physicists asking their national government for more resources.

In his talk back in 1952, Feynman had focused on two topics: the value of science and the outdated nature of physics teaching in Brazil. He refrained from explaining how to teach properly, because he confessed to not being competent to do so, as his identity as a physicist was that of a researcher, not a pedagogue. In his talk in 1963, he dealt with the same topics, and refrained from revealing the substance of good teaching because, he claimed, this was the expected job of all conference participants (including himself) for the following days. If any, Feynman's recommendations were a melting pot of neo-liberal recipes, as his emphasis was on laissez-faire, competition, a linear model of economic progress through "applied science" and a preference for private over government intervention. In parallel, the US federal government model for (national and international) science education development involved a straightforward injection of humongous amounts of funding—however, indirectly administrated by private (non-profit) corporations such as the American Institute of Physics and the PSSC.[77] This also included contributions to international organizations such as IUPAP and UNESCO, and the development of a network of political caucuses operating in national and inter-national interests.

Feynman's contribution to the debates on the international reform of physics teaching did not appear to go much further. However, it helps us to see how between the 1950s and 1960s, and across IUPAP's first and second conferences on physics education, there were significant developments that contributed to reshape the identity of the professional physicist. The making of a signature pedagogy for physics contributed to developing an implicit understanding of what physics ought to be, what counted as knowledge, and how its communication and development in the classroom should proceed. In parallel, it increasingly defined a special profession in the emergence of the science education expert, with notorious examples in the managers and workers of national and international projects such as those from the MIT, the OEEC, Nuffield, UNESCO, and the IBECC. Their careers are worth analyzing, as professional connections and transferences happened, and interpretations connecting the individual and the collective, research, teaching and marketing, and the local, national, and international, take the central stage in further investigation. The third conference organized by IUPAP's Commission would be held in London in 1965, under the continuist lemma of "Conference on Education of Professional Physicists."

[77] On the complexities of the "neo-liberal" doctrine in the 1950s and its different parties (admitting or rejecting various degrees and cases of state intervention), see Philip Mirowski and Dieter Plehwe, eds., *The Road from Mont Pèlerin: The Making of the Neoliberal Thought Collective* (Cambridge, MA: Harvard University Press, 2009); and Angus Burgin, *The Great Persuarion: Reinventing Free Markets since the Depression* (Cambridge, MA: Harvard University Press, 2012).