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Kristian H. Nielsen

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Centre for Science Studies, University of Aarhus, Denmark
Research group: History and philosophy of science

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The practice and politics of integrated science teaching in the global Cold War

Kristian H. Nielsen, Centre for Science Studies, Aarhus University

INTRODUCTION

'Scientific literacy is an essential element of modern life and must be introduced in the primary schools as part of the ABC of education. No meaningful preparation for the world of tomorrow can be made without science and technology.' Thus spoke Stephen Oluwole Awokoya, Director of UNESCO's Department of Science Teaching and Technological Education and Research, to imbue the attendees of the planning meeting for UNESCO's Programme in Integrated Science Teaching, held in Paris, 17-19 March 1969, with a sense of the urgency of the task ahead for science teachers and educationalists.[1] He noted that the ferment of activities since the end of World War II had been so great that it aspired to be called a 'revolution in science teaching'. In particular, integrated science teaching seemed to be a promising venue for facilitating science improvement programmes in the developing countries. It would use new teaching techniques to provide children with the fundamental understanding that the natural world is of a piece, with basic insights into scientific method, and with the recognition that science forms part and parcel of contemporary society. UNESCO was keen to support the integrated science teaching trend, launching its Programme to promote the exchange of information, provide technical services to Member States, initiate and support experimental projects, and arrange a series of integrated science teaching workshops.

Today, UNESCO's Programme, which ran from 1969 to 1990, provides us with important insight into the myriad ways in which curriculum workers and science teachers across the globe used the general notion of integrated science teaching to develop their own approaches to science education based on the perceived needs of children and related to the local environment and national and international politics. It allows us not only to trace the geographical and political dimensions of the worldwide enthusiasm for integrated science teaching that emerged in the course of the 1960s and 1970s, but also to probe its diversity. Using material published in the course of UNESCO's Programme while also drawing on existing studies of science curriculum reforms in the USA by John L. Rudolph and George E. DeBoer, this paper seeks to answer the guiding research questions:[2]

- What ideas about integrated science teaching were being promoted by actors affiliated with UNESCO's Programme?
- What's the relationship between ideas about integrated science teaching and the global Cold War context?

- How were these ideas adapted to different local and national contexts in the USA, Europe, the Middle East, Africa, and Asia in the course of the Cold War? In particular, how was integrated science teaching being practiced by different communities across the globe?

CONSTRUCTING SCIENCE EDUCATION IN THE USA

After World War II curriculum reformers in the USA had begun to develop some of the 'revolutionary' science education projects that so enthused Awokoya and others. These reformers were mostly practising scientists who, with the support of their professional organizations and the financial backing of the National Science Education, launched national science curriculum projects aimed at strengthening pupils' understanding of the conceptual structure of the sciences and the process of scientific inquiry.[3] Their education reform effort was unprecedented in scope and impact, not only providing science teachers with comprehensive and up-to-date information about the sciences as well a more accurate image of the nature of science stressing tentativeness and process, but also offering inspiration for curriculum reformers in other countries. The movement was spurred by the immediate shortages of technical personnel brought on by the war in combination with the idea that science and technology are key drivers of wealth and health.[4] It gained momentum due to perceived threats to national security stimulated by Cold War competition with the Soviet Union, culminating in their launching of the Sputnik satellite in 1957, and persistent claims that progressive education developed in the interwar years had failed.[5]

Scientists were prime movers in the US curriculum reforms. During the war, scientists, physicists in particular, had been crucial to development of new weapons, logistical support and devices used for navigation, communication and remote sensing. After the war they profited from their wartime experiences as they developed a postwar, Big Science research culture defined by large-scale, goal-directed projects based on practical problem-solving using sophisticated analytical tools.[6] As scientists gradually realized the extent to which their knowledge and their approaches were useful to tackling a wide variety of different problems, they grew more and more ambitious in extending their consultancy services to government agencies, industries and think-tanks. At MIT, for example, scientists took on examining the threat of Soviet submarine attacks (Project Hartwell, completed in 1950) and the problem of Soviet jamming of Voice of America (Project Troy, completed in 1951).[7] Both Hartwell and Troy were organized as summer studies, bringing together experts from different disciplines who applied their knowledge to perform analysis of the problems at hand and suggest new solutions.

In 1956, Jerrold Zacharias, an MIT physicist and member of the Science Advisory Committee of the Office of Defense Mobilization, proposed a science education project involving instructional movies in physics to Harry C. Kelly, head of the Divisional Committee for Scientific Personnel and Education under the National Science Foundation (NSF). Zacharias and Kelly were both concerned about the lack of scientific and technical manpower, and both frustrated by existing approaches to science education. Scientists, not educationalists, should design curricula and teaching materials for primary and secondary schools. Zacharias easily received the funding required from the NSF (and more) and proceeded to organize what became known as the Physical Science Study Committee (PSSC). From his participation in Project Hartwell, Zacharias had learned that the most efficient way to get high-ranking and busy scientists involved was to organize a kind of summer study and also that an engineering approach to science teaching, responding to pedagogical challenges with innovative teaching tools, would be preferable.[8]

The PSSC quickly developed much grander ambitions than merely producing a number of physics movies, although the film component remained an important part of PSSC's work well into the 1960's. First of all, the PSSC members all agreed with Zacharias that the aim of pre-college science education was not simply to provide pupils with scientific information based on disciplinary and sub-disciplinary knowledge specialization. Much broader goals were envisaged: First of all, science education ought to instil rational and critical thinking in children. Rationality, for the PSSC'ers, was defined by the natural sciences, the model of which was physical science. Learning about empirical methods and ways of reasoning in physics, therefore, would serve the larger purpose of counteracting irrational and science-sceptic tendencies in American culture. Secondly, changing science education was seen as a prerequisite to changing public understanding of science and enhancing public perception of science. Science, from PSSC's perspective, was not merely a body of knowledge but, perhaps more essentially, an inquiry process that required nurturing an inquiring frame of mind. Children aka future citizens needed to learn about these aspects of science in school. Thirdly, by emphasizing the rational, existential and holistic features of science, i.e. physics, PCCS wanted to reinstate science at the core of Western cultural thought.[9]

With lavish funding from the NSF – John L. Rudolph estimates 'well over $200 million when all was said and done' – the PSSC produced a major new physics textbook, more than fifty physics movies, classroom lab material and several shorter books to be used in physics teaching.[10] The PSSC also had an impact beyond physics education, partly because its efforts were closely aligned with prevalent ideas about national security and competitiveness, i.e. the perceived shortage of technical personnel in the military and in industry, and contemporary threats to American culture, i.e. irrationality, misconceptions about science and lack of public support of science and technology; and partly because PSSC showed that scientists could (and should) be leading reforms in science education. In the wake of PSSC followed the Biological Sciences Curriculum Study in 1958, the CHEM Study in 1960 and other US academic study committees or think tanks established on the subject of curriculum reforms.[11] Some disagreement with respect to the scope and content of the reforms were expressed – for example in disputes between mathematicians involved in the School Mathematics Study Group and physicists involved in the PSSC – but generally most reformers shared the basic ideas of the PSSC.[12]

Although the PSSC did not promote the term integrated as a common denominator for their new programs, there are several ways in which we might think about their efforts as a first-generation, single-discipline attempt in integrated science education. The PSSC promoted the view that physics should be taught as an integrated whole, not just as scattered unrelated pieces of information or as separate physical laws. Children should realize that physics and bordering disciplines such as chemistry and geology were joined together in an elaborate conceptual structure aimed at describing inorganic nature as a unified whole. Moreover, physics teaching ought to be integrated in the sense that children should really just learn how to think and act scientifically, i.e. rationally, methodically and empirically, and then apply this intellectual competence to all sorts of problems. Finally, physics education also had to be seen as integrated with society, albeit in a somewhat indirect manner, based on the idea that teaching physics was important to attracting more young people to careers in science and education and to changing popular views of physics in particular and science in general.

INTEGRATED SCIENCE EDUCATION IN THE GLOBAL COLD WAR

The ideological struggle of the Cold War shaped the curriculum reforms initiated by PSSC and other groups but also allowed some of the basic ideas about integrated science education to travel easily to other countries and to international organizations. PSSC's battle against growing irrationalism and public misconceptions about science was informed by a larger domestic campaign spreading fear of the growing influence of communism in the USA, initiated in 1950 by Senator Joseph McCarthy.[13] When scientists like Zacharias talked about irrationalism, they would more or less implicitly include communist beliefs as one of the defining factors of what it meant to be irrational. Integrated science education programs therefore built on the idea that science is incompatible to communism and other totalitarian forms of government. For Zacharias and probably most other scientists involved in designing new science curricula in the 1950's, real science served liberalist, democratic, and capitalist aims.[14]

A growing body of literature dealing with relations between science and US foreign relations in the Cold War has demonstrated that science and technology played an important role in the projection of US 'soft power' or knowledge/power across the globe.[15] Americans promoted the reconstruction of technical infrastructure in Europe for scientific and social purposes as it served the ideological and practical aims of US security policies aiming to keep communism out of Western Europe and undermining it in Eastern

European countries.[16] In what during the early Cold War became known as Third World countries, some US interventions focused on strengthening scientific capabilities and building industry and infrastructure in order to stimulate the kind of development that meant ‘becoming more like America’.[17] These development initiatives would also help keeping communism at bay and thus serve to promote US’s strategy of containment.[18]

If integrated science education had to the potential to prepare children for careers in science and engineering, but also make them more positively inclined towards liberal democracy and capitalist values, then it comes as little surprise that integrated science would also appeal to political reformers driven by the same kind of fears and trying to enforce the same kind of social changes in other countries and on an international scale. Integrated science, i.e. science education reforms along the lines suggested by PSSC and others, was so strongly shaped by the geopolitical agendas of the Cold War that it was a natural ‘export item’. Even before similar curriculum reforms had been initiated in other countries, it could be argued, integrated science already had prevailed on an international scale, simply because it was so closely linked to the arrival of US-like liberal internationalism, capitalism and modernization.

THE EARLY DAYS OF SCIENCE EDUCATION AT UNESCO

Although UNESCO and its mandate for international cooperation in education, science and culture can be traced back to the League of Nations resolution on 21 September 1921, UNESCO only came into existence in the wake of World War II in 1945-46 with biologist Julian Huxley as its first Director.[19] Science, or rather Scientific, was included into UNESCO’s charter only in consequence of intense lobbying by scientists during the preliminary meetings and negotiations that took place during the war.[20] In the early years, UNESCO strived to define science, like culture and education, as a transnational and non-partisan activity that should be promoted with no or little reference to national interests. As a result UNESCO viewed its role in the promotion of science, science policy and science education as a relatively passive one. However, the intensification of the Cold War during the 1950s and, more specifically, the admission of the Soviet Union and several of its Eastern bloc allies into UNESCO in 1954 meant that UNESCO programs increasingly became more focused on achieving specific goals. In the field of science policy, for example, UNESCO actively began to pursue the norm that science and technology should be promoted for the benefit of less developed countries and, consequently, that the planning of science policy would be indispensable for all nation states.[21]

From 1950 onwards science teaching featured explicitly in UNESCO’s program. The first initiatives aimed at helping teachers to teach efficiently by providing them with the catalogues of materials and manuals for teaching. The UNESCO Source Book for Science Teaching published in 1956 was translated into 40 languages and became an international bestseller with 400.000 copies sold.[22] The book proved particularly useful to teachers in regions where previously there had been little or no equipment for practical science teaching. Initiatives to improve science teaching remained an import task of UNESCO in the year to come, while efforts to institutionalize and focus UNESCO's role in shaping and directing science teaching programs in its member states became increasingly more important.[23]

In 1961, physicist and father of folk singers Joan Baez and Mimi Fariña, Albert Vinicio Baez was invited to UNECSO to become the first Director of the Division of Teaching of the Basic Sciences in Higher Education.[24] Baez received his PhD in physics from Stanford University in 1950, around the time where Jerold Zacharias got involved in Project Hartwell. Like other physicists in the early Cold War period, Baez' talents were in high demand. True to his pacifist and Quaker beliefs, however, he declined lucrative job offers in the military-industry complex, thinking 'that this was not the ultimate road to peace, for a physicist to spend the rest of his life designing the operations of war. In 1958, Baez joined the PSSC where he contributed to the preparation of instructional movies, teacher guides, standardized tests, and recommendations for inexpensive laboratory equipment to use in conjunction with the PSSC *Physics* high-school textbook, which appeared in 1960. Baez stopped working for PSSC in 1960, the year before he moved to Paris with his family to pursue his career at UNESCO.

Baez was instrumental in translating some of the basic ideas underlying the science curriculum reforms promoted by PCCS and others into UNESCO's policy for higher education in science and engineering. At UNESCO science education was placed in the Department of Natural Sciences. Baez took with him the assumption that science education reforms should be left to scientists who in collaboration with specialists from other fields could best design and evaluate new teaching methods and curricula. He particular espoused the idea that the development of a range of new technical teaching aids, such as concept films like the ones developed by PCCS'ers, pre-programmed self-instructional devices, and take-home kits for laboratory work, could be applied to help teachers. The role of UNESCO was to sponsor the development of such teaching aids, all of which should emphasize comprehension of basic principles rather memorization of facts, but also to carry out systematic evaluations of their applications.[25] On a more general level, and fully in line with the ideology of the American curriculum reformers, Baez proclaimed that science had made 'modern life physically more bearable and attractive' and 'helped remove the ignorance and fear from the minds of men'. Consequently, it fell on UNESCO to encourage 'any nation that wants to derive the ultimate benefits from science' to create competent bodies for science and engineering education: 'A country without a significant number of high levels scientists and engineers cannot be in the main stream of modern life'.[26]

When Albert V. Baez resigned in 1967, the fundamental ideas of UNESCO's Division of Science Teaching already were well established.[27] They were roughly convergent to the educational and political philosophies promoted in the US by groups such as PSSC, and in other countries by other actors such as the Nuffield Foundation in the United Kingdom. They generally built on the premise that investments in science teaching were of crucial importance not only to economic progress by attracting more young people into science and engineering, but also to the eradication of ignorance, superstition and oppression by means of scientific literacy. Teaching basic science at all levels of the educational system, thus, would be key to the development of human and natural resources in all countries, in particular those in the process of incipient modernization. States across the world ought to recognize this and make the steps necessary to institutionalize science education as an issue of government. Achieving effective science teaching, however, for people like Albert V. Baez having switched from science and engineering to education, not only depended on government but more crucially on developing the right kind of teaching tools. 'A technology of education now seems to be a real possibility,' wrote he in 1962.[28] Five years later it was envisaged that UNESCO engage on 'a bold programme' to ensure that science teaching across the world would be based on new tools and new curricula stressing continuity at all levels from pre-school to the university and emphasizing the fundamental structure of the sciences and the unity of their method, i.e., experimentation and inquiry. Science teaching itself should also be experimental, testing new techniques and new material.

INTEGRATED SCIENCE IN THEORY AND PRACTICE

On 17 June 1969, when Stephen Oluwole Awokoya made his opening address in Paris at the planning meeting for UNESCO's Programme in Integrated Science Teaching, there were high hopes with respect to the future achievements of the programme. As former minister of education in Nigeria, Awokoya was fully aware that in order to make the new science teaching techniques available to children in developing countries special attention had to be given to primary schools. Most of the material available at the time had been developed for secondary or tertiary schools. In fact, UNESCO's own efforts in science teaching under Albert V. Baez had been mostly directed towards higher education. Awokoya stressed that most children in the developing regions of the world do not go beyond primary education when they have any formal education at all. Introducing science to even the youngest school children and pre-schoolers was necessary, or they would miss out on it entirely. Integrated science, he argued, was well suited to this purpose for two reasons: Firstly, primary school pupils in developing countries need only to learn the most basic scientific principles and need not be concerned with the subtler differences between, say, physics, biology, and chemistry. Secondly, teaching children to direct their natural-born curiosity into systematic inquiry and experimentation would allow them to find out things on their own.

> The primary school child on coming to school has those interests which represent his potentialities as a future scientist. These interests should be the starting point of our integrated science approach. … These interests are our best allies in leading the child to explore nature and nature's ways. In his endeavour to find causes, he asks questions. In the past he was told to be quiet or given superstitious or untrue explanations. Today, he must be given scientific explanations and led to find out the answers by trial and error, by experiment and verification. There are the living roots from which scientific knowledge can grow.[29]

In his address Awokoya introduced the notion of an environmental approach in integrated science teaching, which in his opinion could serve as an integrating feature for all of the participants in the programme regardless of their cultural or political background. 'Wherever we may come from, whether from the East or the West, from the frigid or torrid zone, from the rainy forest or desert lands, science can and should always begin by a study of the environment that shapes our destiny', he said.[30] All children like to see the rainbow and seek explanations for it. However, differences remained. The Swedish child normally would be presented with scientific explanations for the colours of the rainbow and experiments pertaining to the wave nature of light. In contrast, the Nigerian child would be told that the rainbow is the excreta of the boa and if one can find the place where the rainbow touches the ground a little bit of its faecal matter can make one become a millionaire. The environmental approach, Awokoya emphasised, had to tackle head-on such non-scientific beliefs, while also serve to give the children an exciting scientific adventure.

Although Awokoya had called for 'a sort of basic philosophy, if not a complete consensus as to what we are to do in basic science teaching', divergence with respect to what integrated science teaching really meant soon appeared.[31] This was partly an intended effect of UNESCO's programme, designed as it was to collect, disseminate and discuss information about integrated science teaching from all over the world. The programme included a series of international conferences, and six volumes of *New trends in integrated science teaching* (1971-1990) were published, together with regional contributions on the same theme. The breadth of integrated science already was already prominent in the first volumes of the UNESCO series. A few examples from the realm of science teaching theory and practice, respectively, will be provided in the following to demonstrate the kinds of discussions and activities that were pursued under the auspices of integrated science. All of the examples are taken from the first volume of the *New trends* series.

James Rutherford and Marjorie Gardner, both affiliated with Harvard Project Physics, a national curriculum development project to create a secondary school physics education program in the US inspired by the innovative approach of the PSSC, first approached the topic of integrated science from the perspective of philosophy of science.[32] They pointed out that most philosophers of science, indeed most scientists, would claim that science 'is not and cannot become unified', and that it is 'no longer widely believed that there is such a thing as the scientific method'.[33] Despite the fact that science from the viewpoint of philosophy of science appeared to be highly dis-unified – 'there seems to be a variety of methods used by different scientists in different fields at different times', they wrote – Rutherford and Gardner still maintained that pursuing integrated science teaching was valuable. However, other rationales than reference to the fundamental nature of science had to be put forward to buttress the case for integrated science. Curriculum developers and science teachers rather had to consider what the students' or pupils' need were as they designed and applied their integrated science teaching methods and curricula. From this perspective, Rutherford and Gardner concluded, integrated science teaching was certainly a useful approach in that it prepared children for coping with the world they encounter, a world which for most children, indeed most people, is characterized by a high degree of unity.

Other contributors to the first volume of *New trends in integrated science teaching* were less hesitant than Rutherford and Gardner to see science as a more or less unified and coherent whole at the level of method and process. For example, Robert Francis and Hubert M. Dyasi, both of the Science Curriculum Development Centre at Njala University in Freetown, Sierra Leone, stated: 'In its process, science uses logic to build up an organized and tested body of knowledge on which to draw for further investigations of nature'.[34] The American Association for the Advancement of Science in its contribution, extracts from the booklet *Science – A Process Approach*, depicted science as a collection of scientific behaviours: 'Scientists do observe, and classify, and measure, and infer, and make hypotheses, and perform experiments'.[35] Integrated science teaching according to this approach would facilitate children's adaptation of such behaviours in order to develop their intellectual skills and human capabilities. The same basic philosophy inspired many other projects such as the Indian Science Learning Through Inquiry, prepared by the Community Science Centre at Ahmedabad, which aimed at providing children with 'a glimpse of how a scientist works and how a scientist is able to recognise the accurate nature of things by observation, hypothesis, experimentation, conclusions, and predictions'.[36]

Others again accentuated the unifying conceptual structure of science as a focal point for integrated science teaching. Morris Shamos, who much later expounded the view that only those seeking careers in science should have to wrestle with a full scientific curriculum, presented the Conceptually Oriented Program in Elementary Science (COPES) for kindergarten through sixth grade.[37] COPES aimed at focusing the attention of children on the 'great ideas' in science, i.e. 'the broad, inclusive conceptual schemes in terms of which we seek to account for the familiar facts of nature'.[38] The five conceptual schemes included in COPES were:

1. The structural units of the universe (from atoms and molecules to stars and galaxies)
2. Interaction and change (from chemical reactions to geological events)
3. Energy conservation
4. Energy degradation
5. The statistical view of nature (Brownian motion, Mendelian laws, etc.)

Recognizing the difficulty of identifying great scientific ideas that would fully express the views of all scientists and all science educators, Shamos nevertheless proposed that the conceptual schemes approach would assist children in developing an understanding of 'the nature of matter' at different levels of sophistication. Having such a definite objective, he claimed, would not only provide teachers and children with a clearly defined goal, but also, more importantly, give 'them a cohesive picture of science rather than a series of disjointed topics'.[39]

Whereas most of the contributions presented so far were more or less based in philosophical reflections about the nature of science and/or the nature of nature, some were also concerned with the integration of integrated science teaching and social issues. The Tel Aviv Elementary Science Teaching Project, for example, adapted the new integrated science teaching approaches to schools in Israel for the sake of educating 'citizens out of an ultra-heterogeneous population'.[40] Encouraging the development of systematic thinking and adjustment to 'a modern pattern of life', science teaching would have general importance to the establishment of a modern nation state based on scientific rationality and modern technology. A large population of Israelis children were 'culturally deprived', as the authors, Meir Feuchtwanger and Eugene Kaplan of Tel Aviv University, put it.[41] These children in particular needed to be inculcated with scientific knowledge and methods of acquiring such knowledge. The teaching project, much like the project of the American Association for the Advancement of Science described above, therefore aimed at behavioural change. One of its teaching units, called Things we require for good health, was designed not to teach specific facts about bacteria, but rather to make children familiar with scientific behaviour such as observation, prediction, classification and experimentation. Ultimately, the unit aimed at preparing the children to keep basic rules of hygiene such as washing your hands and brushing your teeth, while also instilling a sense of scientific reasoning into them.

'Ask the Ant Lion' was the name of a science teaching unit developed and tested in the course of the African Primary Science Program, funded and organized by the Educational Development Center in Newton, Massachusetts.[42] The unit exemplified the environmental approach in integrated science teaching that was also propounded by Stephen Oluwole Awokoya in his opening address in 1969 (see above). Ant lions are small predatory larvae that eat arthropods, mainly ants. The ant lions are best-known for their small funnelshaped sand pit traps built to capture ants and other insects. The 'Ask the Ant Lion' teaching unit was tried out at Ukonga Primary School close to Dar es Salaam, where the children already knew ant lions, but not much about them. The unit required the children to become more acquainted with ant lions by asking questions. 'If you have a problem', the general theme ran, 'ask the ant lion': How do you move? Where do you live? How do you make your pit? Why do you make your pit the way you do? Etc. The instructor, Joseph Elstgeest, remarked that people upon hearing about the ant lion unit, often would smile benignly, expressing their conviction that an unimportant, low, stupid little ground-dwelling insect like the ant lion could not possibly be a proper object of science instruction in the schools. What does it accomplish? What is the use? His reply:

> My strongest and only argument is a class of children, busily engaged in experimentation with ant lions; their eager questions, their attempts to find answers to their problems, their growing satisfaction at being able to ask the ant lion, and their growing realization that they do get the answers without being told, but through their own efforts. And, if the argument is still not settled, look for the teacher. Often you have to search for him among his children, as engrossed in their investigation as they are.[43]

One of the conclusions of the African Primary Science Program was that there was no shortage of interesting science teaching units and new teaching tools.[44] Rather, good teachers and people with experience and expertise in continuous curricula renewal were in demand. Also, evaluating the outcomes of the many initiatives in terms of student achievement proved to be demanding in terms of human and financial resources. Thus, more efficient, standardized evaluation schemes were called for. These conclusions seemed also to have been reached by the people involved in UNESCO's Programme in Integrated Science Teaching as the subsequent volumes in the *New trends* series were dedicated to the education of teachers and to evaluation.[45] It is beyond the scope of this paper to delve more on these particular issues; suffice to say that the diversity of approaches to teacher education and student evaluation, respectively, was as high as the diversity of approaches to integrated science teaching itself, witnessed by the examples drawn from volume 1 above.

TRENDS IN INTEGRATED SCIENCE TEACHING

By the time of publication of the fifth volume of *New trends in integrated science teaching* in 1979, time seemed ripe for reflection on what had been achieved so far.[46] The volume was based on the proceedings of an international conference organized in April 1978 at the University of Nijmegen in The Netherlands, about ten years after the conference in Varna (Droujba), Bulgaria, which originally had spurred the initiation of UNESCO's programme.[47] Several surveys of existing integrated science curricula and different strategies for implementing integrated science teaching in schools resulted from Nijmegen conference, some of which will be treated here.

Sheila Haggis and Philip Adey of UNESCO's Division of Science Education and the Centre for Science, Chelsea College, London, respectively, in their review of integrated science education worldwide analysed information on some 130 curricula, which had been published or were intended to be published, and which had been tried out in actual classrooms before (intended) publication.[48] Most of the science curricula had been designed for primary and junior secondary schools. And most of these curricula were assessed as being partially or totally integrated in the sense that very little or no disciplinary differentiation in the range of topics and teaching methods could be discerned. The focus on primary and junior secondary schools, the authors wrote, reflected the awareness that had developed in most countries that science should form part of general education of all citizens. The majority of the courses designed for use in primary school curricula were based on direct pupil experience with concrete material. Like the 'Ask the Ant Lion' unit described above, these courses emphasized observation, inquiry and exploration of local environments. They also implied a major shift in the role of the teacher from purveyor of information to facilitator and participant in learning processes – recall Elstgeest's description of the teacher being as engaged in ant lions as the children. This change in role, Haggis and Adey concluded, posed a serious problem in effectively introducing integrated science courses into primary education and enhanced the need for teacher training.

Wynne Harlen, who later became Professor of Science Education at Liverpool University, pointed out in her contribution some of the strengths and weaknesses of implementing integrated science courses in primary schools.[49] The central issue, she stated, was how to balance the emphasis on content, i.e. the facts, principles and concepts that help children in understanding their environment, and the emphasis on the skills and behaviours which children use to learn something. Primary school teachers putting emphasis on content might find themselves challenged on the amount of factual science knowledge required, while teachers applying the inquiry-based and child-focused model would need to rethink their role as a teacher. One of the major obstacles for integrated science courses at all to appear in the school curriculum, Harlen said, was the lack of external motivation in the form of centrally imposed syllabuses. Even if prepared material was available and the teacher has incentives to adopt it, it often turned out that 'teacher's guides are used as recipe books and teachers soon begin to leave out pupil activities, returning to a lecture and demonstration style of teaching'.[50] Simply disseminating teaching materials such as guides, kits of equipment, films and other audio-visual aids from centres of development (typically developed countries) to users in 'peripheral' less developed regions had proved to be an ineffective strategy for implementing integrated science teaching. Harlen instead proposed the creation of local centres to make sure that science was integrated into the curriculum and to provide long-lasting support for teachers at the regional or national level.

A group of authors looked for trends in the instructional objectives and integrating techniques of integrated science courses.[51] Like Haggis and Adey, they surveyed well over 100 courses and discovered a huge breadth. Some courses aimed at developing different kinds of scientific literacy in children: from understanding the conceptual basis of science to acquiring the manipulative skills of scientists or simply valuing science as a cultural achievement. Other courses pursued personal growth, developing confidence for independent inquiry and knowledge applicable to many different situations. Others again concentrated on socially relevant issues in order contribute to the improvement of one's life and one's community. With respect to techniques for selecting and integrating different kinds of content, diversity also was evident. Some courses adopted a scientific perspective, using science content or methods as guidelines for the organization of content; others started out with more practical or personal considerations about what the course ought to achieve. The diversity notwithstanding, the authors concluded:

> Just as there has been a trend toward a rapid increase in the number of integrated science programmes existing world-wide, there have also been very distinct positive trends in the changing character of these programmes. In general, the trends seem to indicate a greater focus on the importance of the learner and a greater understanding of the nature of science as an integrated whole. Trends are seen toward increasing relevance, greater attention to the needs of special groups of students, more and broader objectives (especially affective ones), tying science more closely to society, more complete and creative integration, and increased flexibility in programme design. One especially important trend is the greater attention paid to research and theory on how children learn.[52]

Partly due to the lessons learned in the course of the programme for integrated science teaching, UNESCO from the beginning of the 1980s onwards began placing more on the application of science and technology education to the needs of daily life and the development of society. In 1990 the final volume of the *New trends in integrated science teaching* was published containing many more examples of integrated science teaching, discussions of the meaning of integrated science and an annotated bibliography with 373 entries.[53] No mention of why UNESCO since the mid-1980s had stopped being active in the field of integrated science teaching was made.

DISINTEGRATING INTEGRATED SCIENCE TEACHING?

By way of conclusion, the guiding research questions will be addressed, and an attempt will be made to draw some historical implications for the world of science education today.

Simply looking at what took place in the course of UNESCO's Programme in Integrated Science Teaching, it should be clear by now that prevailing ideas about integrated science teaching, and the ways in which integrated science was actually taught, were highly diverse. As David Cohen argued in his introduction to the fourth volume of the *New trends in integrated science teaching series* dealing with the evaluation of integrated science teaching: 'In summary, consensus is lacking concerning the "pros" and "cons" of the study of science as comprising "separate subjects", or as "integrated science"'.[54]

The disagreement ran even deeper than Cohen surmised and pertained to very idea of what integrated science really was. Some would argue that integrated science teaching reflected the fundamental unity of science and nature; others acknowledged that science was highly heterogeneous, just like the environments that children live in composed of natural as well as cultural entities. Some thought integrated science teaching should be aim at preparing children for modern life by way of enculturating them into the world of scientific rationality and contemporary technologies. Others were more concerned about their personal skills. Others again drew close connections between integrated science teaching and scientific literacy. Sometimes actual integrated science teaching had very little to do with what may meaningfully be called science; other teaching units simply used integrated science as a way to combine two or three closely related disciplines. Most often, all of these different ideas and practices seemed to co-exist in an unproblematic manner, but there were also attempts to differentiate conceptually between different meanings of, and arguments for, integrated science.[55]

The original motivation to do something about science teaching sprang from science curriculum reforms in the USA and elsewhere during the 1950s and 1960s. UNESCO's first Director of Science Teaching, Albert V. Baez, had been directly involved in the activities of one of the most prominent curriculum reform groups, PCCS, and when Stephen Oluwole Awokoya launched UNESCO's Programme in Integrated Science, he explicitly referred to the science teaching revolution with origins in the USA. John L. Rudolph has convincingly argued that the science curriculum reforms initiated by groups such as PCCS were firmly embedded in US Cold War politics.[56] Science teaching formed part and parcel of a general mobilization of scientific and technological resources to enhance economic growth and national security, and science literacy was seen as a bulwark against irrational forces such as communism. When the urge to tackle science teaching was transferred to UNESCO, it also was being shaped by new political forces, in particular the notion of development. Science teaching, it was believed, was essential to allow developing countries to embark on the very same path of modernization that had transformed the developed countries in the time span of just one hundred years. Science teaching was seen as a way in which to enable nothing but a mental shift in 'non-Western cultures', as it was explained in the introduction to the planning meeting of UNESCO's Programme in 1969

> Belief systems which control learning are often markedly different in Western and non-Western cultures. For children living in societies which traditionally are non-scientific in the Western sense, faith in the capacity of man to discover and interpret the nature of the physical world and thereby to control it to his personal advantage may imply something of an intellectual and moral quantum leap. Without such a change, it is possible to acquire scientific knowledge and techniques, but such learning will represent nothing more than replacing one authoritarianism for another, with the new being no less sterile and inhibiting to intellectual development than the old. Sharpening the sense of curiosity of children in a manner that leads to their independent and intelligent thinking needs to be cultivated. Integrated science teaching was identified as being one of the most promising hopes of achieving such high aims.[57]

Integrated science teaching was seen as an ideal way to bring science into the classrooms of primary schools, and as such it fitted well with UNESCO's desire to adopt integrated science teaching as a means of development. In the developing countries most children did not go any further than primary school, if they went to school at all. Science teaching therefore had to be integrated into the general education received at this early stage, if children in developing counties should receive any kind of science-like training. Integrated science teaching in this context implied that science could and should be taught to children at all levels, even pre-schoolers. Coincidentally, during the 1980s curriculum reformers in the USA and elsewhere would also become increasingly interested in the different meanings of science-for-all, including the idea that science could and should be taught in primary as well as secondary and tertiary schools.[58] In 1985 the American Association for the Advancement of Science founded Project 2061: Science for all Americans. Eight years later, the Project published its *Benchmarks for Science Literacy*, detailing what all students should know and be able to do in science, mathematics and technology by the end of grades 2, 5, 8 and 12.[59] Although terms like integrated science feature only sporadically in this ambitious initiative, it seems fair to conclude that UNESCO's Programme in Integrated Science Teaching played a small, but not insignificant part in the widespread integration of science teaching into all levels of formal and informal education across the world. In the process the very idea of integrated science somehow disintegrated.

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