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PROFILE OF EDUCATORS

Albert Vinicio Baez and the promotion of science education in the developing world 1912–2007

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Alberto Vinicio Baez was a pioneer in the field of international science education. He was a physicist who played a leading role in UNESCO's efforts to support science education globally. His research in the physics of light led to the development of an X-ray microscope and of imaging optics. He participated in projects to improve science education in high schools in the United States in the 1950s, a period of intense interest on this topic.

In 1961 he was invited to join UNESCO to establish the Division of Science Education. In this position he wrote numerous papers, organized and participated in regional and international conferences, and studied and supported the development of projects to advance science and technology education in developing countries, with a special focus in secondary schools. The programme established the importance of science education, developed low-cost science kits, films and a structured, high-quality curriculum to support physics teachers in Latin America, chemistry education in Asia, biology education in Africa and mathematics education in the Arab States.

Baez's chief intellectual contributions to the field of science education centered on the development and dissemination of the ideas that it was necessary to democratize access to high-quality education in developing countries, that science education should focus on developing the capabilities needed to solve practical problems, and on the role of interdisciplinarity and social responsibility as core foundations of science education. He also articulated why high-quality science and technology education to improve living conditions in developing nations would contribute to addressing common global challenges faced by humanity, particularly achieving sustainable forms of human environmental interaction, reducing poverty and uncontrolled demographic expansion, and promoting peace.

His writings and work to improve science education in developing countries reflect a theory of educational change that recognizes the synergies that result from engaging multiple stakeholders to initiate and sustain innovation and to institutionalize large-scale change. He favoured approaches that brought together scientists and teachers, and

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designers and learning specialists, to the task of developing curriculum, instructional materials and support systems to create rich educational environments that help students develop creativity, inquiry and the ability to design solutions to practical problems through scientific knowledge and understanding. He conceived of policy and programmes as learning opportunities that should be guided by a clear definition of the intended purposes of science education that would permit progress measurement and comparative analysis.

Life and career

Albert Baez was born in Puebla, Mexico, in 1912. He immigrated with his family to the United States at the age of 2. His father, Alberto Baez, was a Methodist minister, and his mother, Talia Valderama, became a social worker for the Young Women's Christian Association Organization.

Baez grew up in Brooklyn, New York. At the age of 7 he returned to Puebla for a year with his family, where his younger sister was born. The time he spent there, where his grandfather Pedro Flores Valderama, a Spanish immigrant, had established an institute to educate Methodist ministers (Instituto Metodista Mexicano), was critical to the formation of his identity. In an interview he gave when he was 77 years old, Dr. Baez remembered that year in Puebla as very important to him: "It gave me the feeling that I had grown up in Mexico, even though I had only spent the first 2 years of my life and then this year, but since it took place at that particular interval in my life, those formative years, I just felt somehow linked with Mexico. I still feel it. So several advantages accrued from all this. One was that I never forgot my Spanish" (Davis 1990, p. 251).

He attended a manual training high school in New York where he joined the radio club and developed an interest in science and engineering. As a teenager he built electronic devices, including a radio and a television. At a time when very few Hispanics in the United States had the opportunity to access college and were under-represented in the sciences, he earned a bachelor's degree in math and physics from Drew University in 1933, a master's in physics from Syracuse University in 1935 and a doctorate in physics from Stanford in 1950. As a graduate student at Stanford he helped lay the foundation for the newly developing science of X-ray imaging optics. In 1948, working with his advisor, Stanford professor Paul Kirkpatrick, Baez developed the first X-ray reflection microscope, which could examine living cells. Their technique pioneered grazing incidence mirrors to focus X-rays. This X-ray focusing geometry, using two grazing incidence mirrors mounted perpendicular to each other, is known as the Kirkpatrick–Baez geometry. The technique allowed images to be taken that rely on reflections from mirrors at very shallow angles, and did not require specimens to be placed in a vacuum. Berkeley Lab's Center for X-Ray Optics pioneered the use of this system at X-ray synchrotrons. In 1993, the first beamline at the ALS (10.3.1) used a Kirkpatrick–Baez mirror system. Baez was also the person who first suggested the use of Fresnel zone plates with ultraviolet light and soft X-rays, and demonstrated their use in the ultraviolet. Kirkpatrick–Baez-type multi-layer X-ray microscopes have been designed for use in imaging laser-plasma X-ray emission.

Upon graduation from Stanford he worked briefly with the Cornell Aeronautics Laboratory doing operations research, studying aircraft taking off from carriers. He credited this experience with his subsequent lifelong interest in peace. "I began getting the feeling that this was not the ultimate road to peace, for a physicist to spend the rest of his life designing the operations of war" (Davis 1990, p. 248). In 1951 he accepted a

UNESCO appointment at the University of Baghdad in Iraq where he helped establish a physics laboratory. Between 1950 and 1956 he was a professor at the University of Redlands in California, where he continued developing X-ray technology. In 1957 he was appointed visiting professor at Stanford.

In 1958 Professor Jerrold Zacharias invited him to join him at the Massachusetts Institute of Technology (MIT) on a project to improve the teaching of science. In 1956 Physics Professors Jerrold Zacharias and Francis Friedman at MIT had launched a project to improve the teaching of physics at the high-school-level Physics Science Studies Committee. This was one of some 20 large-scale projects to develop the K-12 science curriculum sponsored by the National Sciences Foundation to improve the teaching of science by providing students with early opportunities to engage with authentic science. These projects constituted the first attempt of the United States Federal Government to support science education (Duschl 2000). Baez was invited to join the MIT faculty to work on the development of instructional materials that emphasized fundamental principles in physics, encouraging engagement and understanding as opposed to memory drills. This team produced the high-school textbook *Physics* which appeared in 1960, followed by many subsequent editions. Baez also contributed to the preparation of films, teacher guides, standardized tests, and recommendations for inexpensive experimental apparatus to work in conjunction with the textbook. The films were designed to illustrate phenomena that were too complex, or took too long, for practical experimental demonstration in a classroom. In 1960, working with the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts, he developed optics for an X-ray telescope. Later that year he moved to the faculty of Harvey Mudd College, a highly selective private college of science, engineering, and mathematics, forming part of the Claremont Colleges in California.

Between 1961 and 1967 he was Director of UNESCO's Division of Science Teaching. He also served as chairman of the Committee on the Teaching of Science of the International Council of Scientific Unions.

In 1967 he wrote a paper for the United Nations Economic and Social Council Advisory Committee on the Application of Science and Technology to Development, in which he established the implications of the need for science and technology as engines to support economic and social development. He proposed the need for fundamental scientific literacy: "Science has had such a profound effect on modern life both at the practical and philosophical levels that no man can consider himself in the mainstream of modern thought if he remains a 'scientific illiterate'" (Baez 1967a, p. 1). In this paper Baez also explained that science education constituted an appropriate field of practice and of study to advance a science of teaching and learning, utilizing the most modern tools of educational technology. He explained that the conditions in science classrooms throughout most of the world were not conducive to the appropriate development of scientific skills: "Lack of facilities and materials for experimentation has often encouraged stereotyped and authoritative teaching of science instead of an investigative and experimental approach. In science teaching, the necessity of learning by experimentation is of paramount importance. The greater part of the world still lacks sufficient laboratories and equipment, and as a result the foundations of science (observation and experimentation by the students, followed by interpretation of the results) are often missing in science teaching" (ibid). He proposed an ambitious international agenda focusing on the development of pilot projects in all regions, improving teacher education and establishing an international science teaching center to improve science teaching in developing countries (Baez 1967a). That same year he published a college textbook on physics (Baez 1967b).

Upon retiring from UNESCO he returned to the United States, where he worked for several years with Encyclopaedia Britannica, producing more than 100 educational films on physics. His work at UNESCO on integrated science led to his interest in environmental education. Between 1979 and 1983 he served as Chairman of the Education Commission of the International Union for the Conservation of Nature and Natural Resources. As Chairman of the Commission on Science Education of the American Association for the Advancement of Science he published an influential article outlining his view on the goals of education for the 1970s and how science education was central to achieving them. In this article he articulated that promoting conservation of the environment was a key goal (Baez 1974). He served on the advisory board of Scope, Sequence and Coordination, an organization that developed an innovative high-school curriculum with funding from the National Science Foundation.

As a lifelong pacifist and Quaker, Baez opposed the Vietnam War and was active in many peace and humanitarian programmes. After his retirement, Dr. Baez occasionally delivered physics lectures and was president of Vivamos Mejor/USA, an organization founded in 1988 to help impoverished villages in Mexico. Its projects include pre-school education, environmental projects, and community and educational activities. In 1991 the International Society for Optical Engineering awarded him and Kirkpatrick the Dennis Gabor Award for pioneering contributions to the development of X-ray imaging microscopes and X-ray imaging telescopes. In 1995 the Hispanic Engineer National Achievement Awards Corporation (HENAAC) established the Albert V. Baez Award for Technical Excellence and Service to Humanity. Dr. Baez himself was inducted into the HENAAC Hall of Fame in 1998.

Core educational contributions

His educational ideas are formulated in greatest detail in his book "Innovation in Science Education World-Wide", published by UNESCO in 1976. In this book Baez draws on 25 years of experience in the field of science education and on some of the emerging ideas at the time. His core contributions center on the importance of providing all students with high-quality science education, with an emphasis on technology, on developing the ability to solve practical problems, and to inform life decisions. He thought science education should be practical, relevant and appropriate; that it should promote adaptability to change, focused on improving the wellbeing of the poor; and attentive to the interdependence into which the energy and environmental crises were leading humanity; and that it should be capable of continuous adaptation (Baez 1976, pp. 42–43).

Baez was also a strong proponent of interdisciplinary approaches to science education and of the social responsibility of scientists. His writings reflect the perspective of a basic scientist, deeply grounded in the discipline of physics, who is also a comparativist in his analysis of education systems and of approaches to science education. He proposed too that advancing science education in developing countries was crucial to address the main development challenges and saw international co-operation and international development institutions as central to advancing that agenda.

Baez believed that science capabilities were best developed through integrated science courses which would develop the capacity for inquiry and the motivation and ability to solve real problems (Baez and Alles 1973). In his work on science education Baez demonstrated interdisciplinary thinking, drawing from the fields of psychology, systems planning, instructional technology and development studies.

The moral purposes of science education

In Baez's view the importance of improving the quality of science education was predicated on wider moral imperatives. He saw the development of science and technology as important drivers of economic and social progress, and believed that the gap between developing and industrialized countries would only widen unless the former could mobilize the resources of science and technology to address their most pressing problems.

Baez believed that the capabilities to make sound moral judgments about which problems should be solved by science were integral to science education. He saw engineering and technology as application of science to solve problems based on value judgments: "the man in the street, viewing some of the horrors that have emerged from technology, blames the scientists for them. To the extent that these scientifically trained men are working as engineers, they do have the social responsibility to make recommendations based on humane and socially oriented considerations" (Baez 1976, p. 19).

Baez proposed that four global challenges should guide the efforts of science education: population growth, pollution, poverty, and the pursuit of peace. He saw these challenges as shared across nations and forming the base of a necessary interdependence and thus of international collaboration to address them. In his view, a compact to address them should lead to rethinking the concepts of development present in the 1960s and 1970s, which focused principally on economic growth.

Population growth, for example, which is more rapid in developing nations, reduced the opportunities to increase resources per capita, even as these nations grew economically. Given the lower birth rates in developed nations, the gap in resources per capita between developing and developed nations would continue to grow until population growth could be curbed. Pollution was a major contributor to the degradation of the environment, most prevalent in industrialized countries and a challenge that would grow as developing nations industrialized. Poverty, which accounted for the lack of resources to address the basic needs of many people, particularly in developing countries, was made more challenging by growing inequalities within and among countries. The pursuit of peace referred to the disproportionate use of resources to wage war—in the name of peace. "Many scientists and other people believe that the ultimate folly would be the actual use of the nuclear bombs residing in rocket launching silos and in nuclear submarines, but is it not folly to waste the money, resources and talent needed to keep improving those weapons […] when such money, resources and talent might be used instead to solve the problems of overpopulation, pollution or poverty?" (Baez 1976, p. 30).

Serious attention to these four challenges should lead, in Baez's view, to an expanded view of development, less focused on economic growth and more attentive to social and political development, and ultimately to happiness. For the poorest countries he thought it essential to give priority to economic improvement targeted to addressing hunger, disease, malnutrition, and illiteracy. Development should also attend to the reduction of income inequalities and to giving a more powerful political voice to the poor. Technological development should prioritize addressing the needs of the poor. International efforts to reduce inequalities between countries would require significant solidarity in the form of financial contributions from developed countries. He advocated that multilateral organizations, such as the United Nations system, should administer those efforts, to reduce the attachment of political strings to such aid. All of this would require a greater shared understanding of the ultimate interdependence linking all people on the planet. "Recognition that we live on a finite globe with finite resources may force us to move towards patterns of behaviour associated with the concept of world brotherhood"

(Baez 1976, p. 41). The achievement of these goals would, in Baez's view, require major efforts in education.

Baez believed that science and technology could contribute to addressing these shared challenges, provided scientists and citizens developed a sense of social responsibility that would make them competent to guide science and technology towards those goals.

Baez's view of the way in which science education, and teaching social responsibility to guide the application of science, reflected a democratic theory in which better educated, more competent citizens would hold elected representatives accountable to reflect the will of the people, and government officials could in turn create incentives for private firms and scientists to develop technologies responsive to those interests.

> As an example of how social responsibility can be shared by scientists, engineers, legislators and the general public in a democratic country where, in principle, they can influence the course of events, consider recent actions to curb the increase of pollution in the air caused by the automobile exhaust.
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> It is the responsibility of the scientist to understand the laws of nature that relate to the production and propagation of noxious fumes and to inform legislators and the general public about them. It is the task of the engineer to make the necessary breakthroughs in creative design that produce the smog controlling device and it is his/her responsibility to propose its use to management. It is the responsibility of management to make the decision to incorporate the antipollution device in the production plans for the well-being of society as a whole, and it is the duty of the legislature to pass laws requiring the introduction of anti-smog devices. Finally, it is the responsibility of a concerted and well-informed public to exert pressure on their legislators demanding the passage of anti-pollution laws.
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> The science educators of the future must take into account the social responsibility of all groups mentioned above. (Baez 1976, p. 33)

In his conception of the role that science education could play, Baez expressed a humanist view of education, with the broad purpose of developing multiple capabilities and potential. He thought that the industrial and technical superiority of developed nations did not correspond to artistic and philosophical superiority, and suggested that many people in developing countries lived in greater ecological harmony with the environment. "Courtesy and politeness which, at their best, are indicators of warmth and human concern are probably in greater abundance in the developing countries than in the industrialized sectors of all countries" (Baez 1976, p. 34).

Environmental education

Baez's interest in environmental pollution, as one of the four core challenges that science and science education should address, extended into a more sustained interest in environmental issues and environmental education. After stepping down as Chairman of the Education Commission of the International Union for the Conservation of Nature and Natural Resources, in 1985 he organized a major conference on Science and Technology Education and Future Human Needs in Bangalore, India, which focused on human environmental interactions. In his presentation to the conference Baez explained that the satisfaction of human physical needs required access to natural resources and that achieving sustainable environmental interactions required conservation strategies, which in turn required environmental education. He proposed that human-environmental impact was the key educational challenge of the 1980s and called for a global environmental education strategy to reverse the trends that were damaging the biosphere (Baez 1987, p. 45).

The emphasis on learning to do in science education

Baez's view of science education included a heavy emphasis on what we would call engineering education, and on education to develop technological capabilities. He distinguished between science and technology as activities that, while sharing in methods to develop understandings and explanations of the world, had different purposes. While science is concerned with *explaining what is*, technology is concerned with the generation of *practical knowledge.* "It is more a collection of practical information relevant to the task of getting something done" (Baez 1987, p. 16). He saw research and problem solving as two related yet distinct modes of action. "[Science] is the search for knowledge and understanding, [while technology] is the application of knowledge to satisfy human needs" (ibid., p. 17). Baez argued that it was particularly important for science education to develop the capabilities for problem solving, the ability to design solutions to problems. This underlay the importance he placed on science teaching as a process that stimulated creativity and inquiry, what he called the "spirit of change", from which he hoped all people would be able to derive the ability to improve their ability to make good decisions in their lives.

> I am not thinking narrowly of science education here. I would like to see new projects that lead children on, motivated not only by the spirit of science but also by a competence in the solution of problems—what might be called the "spirit of change" through design. (Baez 1987, p. 19)

Baez thought that teaching the development of practical capabilities and understanding required interdisciplinary science teaching: "when you're teaching science to children, you don't break it up into physics, chemistry and biology. You talk about science. So we developed a programme called Integrated Science Teaching [...] the ideal integrating theme ought to be the environment" (Baez 1974, p. 256).

The democratization of science education and an entry point for reform

Baez believed that a good scientific foundation was essential for all citizens. He thought this democratic imperative might not be perceived by many education leaders and decision-makers. To this end, he advocated the improvement of science education at the primary and secondary level to serve "the growing need for all citizens to have a general education which is imbued with both the spirit of inquiry and the approach to problem solving characteristic of technology" (Baez 1974, p. 47). He focused on K-12 science education for several reasons: one was because in many developing countries these are the only levels to which most children would have access. "The majority of children, especially in the developing countries, never go beyond primary school. Whatever they learn of the facts, principles, methods, and spirit of science so as to cope with living in a world that is being revolutionized by science and technology, they have to learn in the primary school." Baez also thought that a solid, general science education would provide a foundation for the improvement of science at higher levels of education. As he compared the various approaches to science education followed by different countries, he argued that one reason for the scientific and technological achievements of the USSR was that the provision of science education to all students expanded the pool of students from which highly competent scientists could be drawn (ibid., p. 73), in contrast to the more limited opportunities to access high-level science content at the K-12 level in school systems where there were different curriculum tracks and in which only some students were taught advanced science.

> If all students in the developing countries, including those in the arts and the humanities as well as those in science, were imbued with the curiosity that characterizes scientists and the competence that characterizes engineers and technologists, all would be in a better position to participate in the solution of the indigenous problems of social and economic development. (Baez 1974, p. 42)

He argued for the involvement of university scientists in efforts to improve science education at pre-collegiate levels, and found the reform of science education at the secondary school level a practical point of entry that would have valuable ramifications in the form of improving science education at lower levels, as well as at the university level. "I would like to see more activities of the kind associated with technology and engineering incorporated into general education even in the early grades and I would also like to see the concept of education broadened to include a sense of social responsibility for all." (Baez 1974, p. 19).

Robert H. Maybury, a former colleague of Albert Baez at Redland and at UNESCO, recalled Baez's passion for educational technology: "During that Redland's period, Al and I were both involved in the national curriculum reform projects funded by the National Science Foundation, Al in the Physical Science Study Committee (PSSC), and I in the Chemical Bond Approach (CBA). This brought us both into working contact with science teachers from secondary schools. I am almost certain that it was Al's prominence as a creative developer of instructional films for the PSSC project that brought him to the attention of the leadership of UNESCO in Paris. Frequent visits to the Baez home enabled me to witness Al's passion for using optical and electronic instruments as teaching aids. His house was filled with every variety and model of film projector, slide projector, overhead projector, camera, tape recorder, etc. Al brought great originality to applying his specialization in the physics of light (optics) to his lectures and talks to student groups" (Maybury 2007).

A theory of educational improvement

Baez distinguished between educational innovation and improvement. The theory of change reflected in his applied work in UNESCO and in his writings conceived that lasting improvement in the teaching of science required the concerted efforts of multiple stakeholders, including scientists, educators, teachers, designers, media specialists, and decision-makers, with the authority to support the introduction of new science teaching practices on a large scale (Baez 1976, p. 9). In this theory, Baez recognized the importance of different forms of knowledge and expertise in putting in place practical systems to support instructional improvement. He saw participation as essential, not only to bring valuable insights into the design process but also to facilitate implementation. This is a concept that he extended to the importance of having local experts in developing countries re-create their own curriculum and instructional materials, rather than merely translate curricula developed by others.

While he did not believe that it was possible to identify one best system to teach science (because the contextual conditions were too varied across education systems), he thought it would be valuable to identify the relevant levers for change by examining comparative experience across nations. To guide such comparative analysis, one should begin with the end in view, defining the characteristics of an adequate classroom environment through which students could learn science. Such an environment would include adequately trained teachers, with time and motivation to attend to their teaching, using democratic pedagogies, fostering discussion in class, a physically comfortable classroom environment, students in good health and appropriately dressed for the weather, flexibility in classroom furniture and ample space, low teacher/student ratios, good instructional materials such as chalkboards, textbooks, self-instructional materials, laboratory equipment, scientific equipment, teacher manuals, classroom libraries, films and supporting instructional materials, a high-quality curriculum, an adequate system of student assessment, a workshop, a culture of inquiry and support to questioning and well-educated teachers (Baez 1976, pp. 51–53). From the definition of these standards, Baez proposed to develop indicators to assess progress and to make systematic comparisons across countries.

From studying several efforts to improve science education in the United States and other countries, and from a review of studies of such efforts, Baez conceptualized the process of educational improvement as including a need for change, a visionary leader working with a team of supporters, adequate financial support, and academic approval and financial support of the education authorities. He also highlighted the importance of sustained efforts to yield not spectacular but continual improvements. From this comparative analysis of international experiences in science teaching, he concluded that: (a) the involvement of scientists in efforts to improve science education was vital; (b) an experimental approach, fostering multiple forms of innovation, was preferable to following a single model; (c) it was essential to provide conditions for local adaptation by local stakeholders; and (d) the involvement of the teachers was critical. He concluded too that a focus on hands-on experimentation was fruitful, that more effort should go into developing software for the media than acquiring sophisticated hardware, and that the knowledge base on how children learn needed to expand and to be at the core of developing novel approaches to science teaching. He emphasized the need for interdisciplinary learning and the need for evaluation.

Intellectual and disciplinary foundations

In his intellectual work on science education, Baez models the same interdisciplinarity that he believed was essential to help students learn science. He was well grounded not just in the disciplines of physics and mathematics, but in the then novel systems approach to educational planning, in operations research and in theories of learning and instruction, as well as in the debates of his time in the areas of educational technology and evaluation and assessment. He also understood with great clarity the challenges that instructional improvement posed in terms of teacher competencies and teacher education.

Between 1945 and 1961 Albert Baez led an active career as a physicist doing research in optics. During this period he published articles in prestigious scientific journals on the measurement of energies of radiation from various targets and on the formation of optical images by X-rays and associated problems involving resolution power and diffraction of microscopes and on telescopes based on ultraviolet and soft X-rays. After joining UNESCO his publications focused almost exclusively on science education.

The contemporary significance of Albert Baez's work

The work of Albert Baez in promoting science education reflects a golden, visionary era of international educational development efforts. At this time, organizations such as UNESCO focused on the expansion and improvement of educational opportunity in developing countries. Baez's first appointment with UNESCO, when he was invited to help establish a physics laboratory and training programme in Baghdad, was during the tenure of Jaime Torres Bodet as the Director-General who led UNESCO to focus on addressing educational needs in developing countries. Torres Bodet, a pre-eminent Mexican educator, had succeeded Julian Huxley as Director-General. At a time when the organization was still struggling to define its identity and mission, Torres Bodet was a force encouraging work on "projects [...] likely to be of the greatest and most far-reaching benefit to the great masses". He was also a great proponent of engaging academics and universities in the pursuit of UNESCO's mission for "without the universities, writers, professors and scientists of the forty-six countries now taking part in its work there would be no reason for UNESCO and UNESCO would not exist" (Torres Bodet 1949).

Baez was later invited to direct the division of science education when Vittorino Veronese was Director-General. Veronese, an anti-fascist lawyer who had served with UNESCO since Torres Bodet's tenure, was also deeply interested in promoting international co-operation and shared the interest in improving education in developing countries. In these first years of the organization, the meaning of the text in UNESCO's constitution—"Since wars begin in the minds of men, it is in the minds of men that the defences of peace must be constructed"—was very significant to many for whom the memories of the devastation caused by the Second World War were still alive. That clarity in the institutional mission of UNESCO probably appealed to a pacifist like Baez.

During those years the organization was, in part as a result of the legacy of Torres Bodet, deeply involved in fostering a massive expansion of access to primary schooling in the developing world and convening regional conferences of ministers of education around the world to set targets for universal primary education. In this context it was both visionary and eminently sensible that a concern to establish the defences of peace in the minds of men would focus on the purposes of instruction and from there on the curriculum of instruction. That this concern for high-quality instruction should also include a concern for science and technology education was one of Baez's most important contributions.

While some of the understandings of how children learn science and about how best to teach them have evolved since the time when pioneers like Baez worked in this field, his concern for the development of creativity and the capabilities to solve practical problems was visionary, as was his emphasis on interdisciplinarity and technological education. A recent report of the National Research Council on the teaching of science concludes: "Expectations of what it means to be competent in doing science and understanding science have also broadened. Beyond skilful performance and recall of factual knowledge, contemporary views of learning prize understanding and application of knowledge in use" (National Research Council 2007, p. 19).

His preoccupation with providing ordinary citizens with a sufficient understanding of science and technology to be able to hold elected representatives accountable and participate in public life expressed a deeply democratic view of politics and of the development process, as valid today as it was 40 years ago. The recent National Research Council Report "Taking Science to School. Learning and Teaching Science in Grades K-8" articulates five goals for teaching science to all children: (a) science is a significant part of human culture; (b) providing a laboratory of experience to develop language, logic and problem solving skills;

(c) it will become a lifelong vocation for some students; (d) the technical and scientific abilities of the nation are key to economic competitiveness; and (e) "A democracy demands that its citizens make personal and community decisions about issues in which scientific information plays a fundamental role, and they hence need a knowledge of science as well as an understanding of scientific methodology" (National Research Council 2007, p. 34).

It was rare for Hispanics in the 1930s in the United States to have the opportunity to access high-level content in science that would develop their interest and prepare them to pursue advanced careers in science. It was even rarer for Hispanics then to complete a doctorate in physics. Eliminating the inequities in science education among ethnic minorities and white students remains an urgent need in the United States (National Research Council 2007, p. 346). In this context it is remarkable that Baez had a successful and productive scientific career as a physicist and, perhaps more importantly, that he would choose to pursue a second career working to expand the opportunities so that more children could learn science in the United States and abroad.

In *Innovation in science education world-wide* Baez argued forcefully for the need to start with clear ends and objectives for science education, which included normative standards that he developed in a description of an ideal classroom for teaching science, as well as comparative research that assessed student achievement and the impact of different approaches and programmes. The comparative study of students' scientific knowledge and skills made possible by recent international endeavors, such as the Third International Mathematics and Science Study and the programmeme for International Student Assessment from the Organization for Economic Co-operation and Development, have indeed become some of the most fruitful avenues to advance our understanding of how to teach science (OECD 2003, 2008).

Baez's passion for the development of capabilities that would allow sustainable human-environmental interactions was timely and premonitory of future environmental challenges. In his book "An Inconvenient Truth", Nobel Prize-winner Al Gore describes how relatively recent is our awareness of the impact of humans in the biosphere. It was only in the mid-1960s that one of Gore's college Professors, Roger Revelle, proposed measuring CO_2 in the Earth's atmosphere, showing how the concentration of CO_2 was increasing rapidly throughout the atmosphere (Gore 2006, p. 30). Baez understood the importance of these emerging environmental challenges early on and explained why science education was necessary to develop the knowledge and the capabilities to understand these challenges accurately and to be motivated to address them.

> Conservation and sustainable development can, and indeed must, work hand in hand to avoid the destruction of the living resources which sustain life. This presents an educational challenge, because it will never be implemented unless a majority of people understand the problem of living resources and are motivated to conserve them. (Baez 1987, p. 37)
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> Although the generation of humane attitudes toward living things is of utmost importance, these attitudes must rest on accurate knowledge—the firm scientific foundation of ecology. The subject of ecology upon which many arguments are based is a science which, in turn, leans heavily on biology, chemistry and physics. (ibid., p. 43)

Besides his substantive contributions to the teaching of science, the moral clarity which Albert Baez used to frame the purpose of science education and the congruence with the moral clarity which inspired many of his professional and personal choices are a central aspect of the legacy of this Mexican–American scientist and educator who passed away in March 2007, at the age of 95.

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