Responsibility in Science

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Ethics, Chemistry, and Education for Sustainability**

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"These are the days of miracles and horrors and hubris. The unveiling of the first synthetic living cell in May (2010) signaled that synthetic biology had emerged as a new technological frontier. Meanwhile, the Faustian bargain of a past frontier—using fossil fuels to provide energy—has come home to roost in the oil-ruined Gulf of Mexico, and in calls to geoengineer the climate. We are an innovating species, engaged in a balancing act. In the decades after the Second World War, innovation fuelled an unprecedented era of wealth creation while keeping us on the brink of nuclear annihilation. The green revolution fed billions while poisoning soil and water and destroying agrarian cultures. Today, synthetic biology and geoengineering portend a future in which managing socio-technical complexity will be every bit as challenging, if not more so. Is there a better way forward? Maybe—if we act fast, embrace our ignorance, and keep experts from taking over.[1]*"*

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1. Sustainability through Chemistry, a Matter of Formation

Have not the experts and their research contributed all these innovations, their translation into services and goods by the respective industries, in chemistry and in other fields of science and technology? Coping with limitations in crucial resources has always been an important driving force for the growth in chemical knowledge and the achievements of the chemical industry: Haber's and Bosch's research on the fixation of atmospheric nitrogen in the form of ammonia was triggered by the shortage of natural nitrate, the Chilean salitre. Similar limitations led to coal liquefaction by Fischer and Tropsch. And a third example is the development of synthetic rubber in the 1930s which eased the dependence of industry on natural rubber from tropical countries—which at the turn of the 19th to the 20th century had brought great profits to the traders, but also great suffering to the people of the countries of origin, for example, the Congo. Today it is not much different. With challenges such as the peaking of the major feedstock of chemical industry, that is, crude oil, and its spiraling price as an energy source, research for more efficient photovoltaic materials is increasingly important.

But what is meant by "sustainability"? Simply carrying on? A connotation of a "better world" resonates in this word; and certainly the development meant is not what resulted from the chemical-industrial progress in the first half of the twentieth century with its two world wars, the blasting away of millions of people possible by Haber's inventions, and the ability to transform coal into the fuel for the war machine, for instance at Auschwitz, where the great poet-chemist Primo Levi suffered as an enslaved laborer-scientist.[2]

[**] This essay is presented as an integrated article composed of contributions to the special symposium "Ethics, Chemistry and Education for the Environment", which was part of the 3rd EuCheMS Chemistry Congress in Nürnberg on August 31, 2010 and contributions to the following discussions. It is our particular intention, with this article, to demonstrate how independent and free partners can reach consensus. This is especially important in these days when all scientific fields formerly considered as indivisible entities (such as chemistry, physics, and biology) are becoming fragmented into many small subdisciplines which seem to drift apart and lose connection. Perhaps this is unavoidable—and the ethical discourse could form a new strong bond.

Sustainability requires scientific investigations into complex research problems, for instance in environmental-chemical and the related biochemical-toxicological or geochemical-physical sciences, with the integration of knowledge from a great variety of other disciplines.[3] The priorities of research are manifold and depend upon the circumstances in which it is conducted. For instance, in a chemical-industrial setting profitability requires that priorities are determined by the demands or expectations of the customers, be they real or conceived. Academic research, on the other hand, is basically a search for truth, its priorities often depending upon the outcomes of previous investigative processes; this situation is comparable to solving a differential equation. Here, besides the intrinsic curiosity of the "Homo ludens", many other indirect factors such as political, cultural, and economic group interests influence and even may determine the direction of the scientific process—though not conspicuously at first sight. Negligence of such forces can lead to a situation in which "science makes (environmental) controversies worse",[3] a problem also known formerly. This may even inhibit the scientific progress,[4] can entail temporary inefficiency of the scientific elucidative process, and signals insufficient knowledge—and education—about the philosophical, ethical, and even spiritual foundations of society and human endeavor.

The powers of chemical practice—and of science-based technology in general—reach global scales today. The "Limits to Growth"[5] are becoming obvious in many areas, as reflected in the economic imbalances of the bank crises of 2009 and other socio-political problems. At the same time, the public's skepticism towards science continues, for several reasons. One of them lies in the fact that the scientific process and its translation into technical and industrial activities and goods require a rigor of thinking and doing which many regard as uncomfortable. But on the other hand, it also stems from the fact that scientists and industrial specialists often have insufficient understanding of the emotional needs and fears of the general public, a result of the almost exclusively intellectual training of the former, while their empathic-ethical abilities remain a matter of serendipity.[6] Profound intellectual-analytical abilities are certainly important prerequisites for professional excellence, but neglect of the "whys and the wherefores", of the philosophy of empathy, entails a heartless process which tends to forget human needs and dreams. To understand and to take this balance of the two facets of human endeavor into consideration should be the responsibility of universities, their teachers, and researchers—not only because they are members of society, but also because schools and universities are traditionally the institutions where the education of the future leaders of a society takes place.[7] Are the old-style universities amenable to change?[8] Or is a complete overhaul of academia needed, a new renaissance?

The disparity and split of "The Two Cultures"[9] and the lack of a cultural view of science and technology have been addressed before.[10] *"Science is not only the methodical and scientific practice but also the idea and way of life of rational cultures. The logical and sociological aspects of research must be complemented by an ethics of research in order to fully encompass science."*[11] The need for the practical realization of ethical principles in chemical education—which is in fact environmental education—is becoming recognized and is reflected by a recent surge of textbooks in scientific and environmental ethics[12] and by conferences and workshops on ethics and science like the "Fora on Ethics and Science for the Environment" in Bayreuth, Ferrara, and Torún,[13] and the symposium on "Ethics, Chemistry and Education for the Environment" organized within the framework of the 3rd EuCheMS Congress in Nürnberg, Germany. But the difficult question remains: How does one practically implement an ethical-empathic education in chemical and other curricula? Western civilization rests on such a culture of love which we are, quite rightly, proud of. Other cultures have different but equivalent spiritual foundations of respect and empathy.

The main problem arises from a profound misunderstanding. The analytical-intellectual approach is a potent and successful methodology to deal with scientific questions, to decide whether scientific hypotheses are right or wrong. But ethical abilities are rooted in human spirituality, the other face of concrete human existence,[14] and here many answers are possible. Black-or-white approaches are invalid, and it must be noted that they may lead to egotism and intolerance. In this realm, empathy, the ways of cognition by the heart, is much more important. If a coldly intellectual education predominates, emotionally impoverished young adults are the result.[8] How can this be avoided without impeding science and technology and—not to forget—keeping enthusiasm and joy in the schools. This is one of the major challenges of the

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present.[6] Contemplating, discussing, and suggesting strategies and tactics at conferences and in various publications is one aspect; their realization is another, more demanding, aspect. And there is not one recipe or method; different approaches are conceivable.

Our intention in this Essay is to develop ideas of how an attitude for caring responsibility can be nurtured in a chemical-scientific context. We do not claim to be comprehensive or authoritative, but we are convinced that such a discourse must be ushered into the halls of science and technology in order to achieve sustainability in the immediate future. One way—we dare to say the only way—to ensure sustainability in the long term is to keep this dialogue alive, training the capability for continual reflection of one's own opinions and spiritual situation in relation to those of neighbors, competitors, and the entire social and natural environment. There are many practical ways towards such goals; together with—but not thanks to!—modern science and technology, they seem realizable. They should be attempted now, within the UN Decade of Education for Sustainable Development.[15]

2. Three Characteristics of Chemistry

Let us consider the three principal characteristics of chemistry that partially distinguish it from other disciplines, namely: 1) inductive knowledge, 2) creativity, and 3) flexibility. All three oblige the chemist to face ethical questions.

1) Truly inductive knowledge means intense experimentation by which levels of knowledge and communication are furthered. Sometimes this occurs through the sacrifice of safety, human respect, or biological limits. So the first ethical question is: What are the ethical limits of experimentation? A particular aspect of this question pertains to animal experiments: Are they necessary, or can the needed data be obtained by alternative methods? And if not: Are the experiments performed with respect for the animals, without physical stress or excessive pain? Is the 3R concept (replace, reduce, refine)[16] applied and are efforts made to reach its full application?
2) Creativity refers to the ability to design new molecular structures or better ways to construct known molecules. Sometimes the original purpose of a process or a substance may be lost and other applications are adopted that are completely different from the original intention, sometimes with catastrophic consequences. One of the many examples in the history of chemistry is thalidomide, which was discovered in the search for new antibiotics and then introduced as a miracle drug against insomnia, coughs, headaches, and morning sickness.[17] Later it was found to hold great teratogenic risk for the fetus when taken by pregnant women in the first trimester. The scientific-industrial community took proper measures in refining toxicological test protocols; but the dramatic consequences for those born in these years with grave handicaps and living today as adults under marginal conditions—they have not been adequately dealt with by society, industry, and politics. Another ethical question is: How far can the discoverer of a chemical or process be held responsible for his or her discovery? Moreover, if the discovery has value for the protection of health or the environment, or as a food component for some people, should it be patentable?
3) Flexibility means the ability to be open for different interests and aims, even if they oppose each other. The principal question for us scientists and researchers today is: How can the technologically friendly face of chemistry be made compatible with ecology?

3. Examples of Practical Approaches to an Ethical Education

If we do not confront these difficult questions, it is no wonder that the public remains rather skeptical towards chemistry, the sciences, and the scientific-industrial community as a whole. The ways in which responsibility and respect for others, and the whole of the environment, can be exemplified are myriad. It is also clear that we are not fully the masters of our fate, and that there is a lot of unpredictability beyond our influence. Nevertheless, let us accept that the way of practicing chemistry—or science in general—influences the well-being of us, of our immediate neighbors, of our environment at large and, depending upon the strength and prevalence of the technology, even of our world. Furthermore, our present living and working conditions are based upon a matrix developed in the past by others who either actively contributed to the shaping or who were used or even exploited. Thirdly, our present actions will determine our future, our children's future, and that of coming generations to an unpredictable but potentially great extent. In other words, we are all shaped by the past and pass through the membrane of the present into an unpredictable future.

Why should we contemplate such questions? The answer is simple: We are responsible for providing our children with the ability and courage to confront the unpredictability of the future. We can demonstrate this most effectively by showing concern for the well-being of those around us, near and far. This can and should be exemplified in education and research, at the universities, through professional practice, and how we reach out to others in the world.

3.1. Where Are the Deficits and How Can They Be Addressed?

When identifying the basic building blocks of a course in practical ethics for sustainability in chemists' curricula,[18] attention should be paid to the consequences of the expanding potential arising from the misuse of chemistry resulting from the advancement of technology and the diffusion of knowledge. The possibility of individuals committing terrorist acts has reached a previously unimaginable dimension.[19] Terrorists are often college-educated persons, and since multicultural societies are developing all around the globe without shared moral values, ethics should be addressed within university curricula. A course in ethics must thus convey not only knowledge but also encourage a culture in which an improved mind is fostered through amended thinking.[6,20] Accordingly, students should be challenged to have: 1) an up-to-date vision of the world-scale sustainability problems; 2) recollection of the major success stories as well as the disasters resulting from criminal or improper use of chemistry; and 3) knowledge of the most important, recent philosophical contributions to the ethical understanding of technological civilization.[6,20–22]

Three of us (F.D., H.F., J.M.) have tested such courses in university curricula at the postgraduate level. The major concerns for global sustainability should be covered and include the topics of water crises, population growth and migration, climate change, and the limits of fossil fuels and mineral resources.

Having a historical view of science in general and of chemistry in particular is important. In fact, we observe that our students often are ignorant of what really happened in Seveso and Bhopal, not only from a scientific perspective but also in terms of the human dimension. Because students may be captured by these stories, recalling these catastrophes is an illustrative way to teach responsibility and precautionary principles. And since the world-shaking disasters call for practical action at various levels, that is, in research, industry, at the political, societal, and individual levels, there are great opportunities for chemistry and science as a whole.

The sciences and the humanities should be brought together to develop a fruitful dialogue between faculties and their students. Such an integrated background is essential for a reformed education: The drama *Prometheus Bound* by Aeschylus, the chorus in *Antigone* by Sophocles, Plato's dialogue *Theætetus*—all of these focus on universal ethical questions, as does Mary Shelly's *Frankenstein, or the Modern Prometheus*. Besides these, a student should have knowledge of today's major thinkers who contribute to our vision of ethical and social problems, for example, Hans Jonas and Ulrich Beck.

Hans Jonas' imperative *"Act such that the effects of your actions are compatible with the permanence of genuine human life"*[22] is considered the basis for ethics in the technological age and an extrapolation of I. Kant's Categorical Imperative. Hans Jonas points out that our actions have multiplicative and cooperative effects as the result of interactions between science, industry, and the economy. The conditions of proximity and contemporaneousness (hic et nunc), the background of ethics in premodernity, no longer apply as criteria for judging modern technical practice. The scope of human action is no longer restricted to the home or city environment—the whole biosphere is involved. And with the concept of the definite integral as the sum of vanishingly small effects, new problems (e.g. of emerging contaminants) can now be understood as the product of many small contributions. The fact of thermodynamic irreversibility illustrates that irreversible harm can occur, and also touches upon the difference between unwitting damage and outright crime. These examples show the proximity and interconnection of philosophy and science in an ethical context.

Understanding the intrinsic duality of human activity is fundamental, as put forward by Ulrich Beck in his book *Risikogesellschaft* (*The Risk Society*).[23] *"In advanced modernity the social production of wealth is systemically accompanied by the social production of risks."* Wealth is tangible and evident. Risks are hidden but can be assessed by using scientific methods and instruments. Here chemometric definitions of errors of the first and second type (H_0 and H_1, respectively) and the associated probabilities (α and β) show their ethical components. Differences in the definition of evidence in a scientific context and in the context of public health and environmental rights[20] help us understand how conventions can have ethical grounds. In fact, the convention in science that errors of the first and the second type are related as $\alpha = \beta = 0.05$ derives from the need to establish clear evidence based upon physicochemical facts and findings. This can be accepted with confidence for the advancement of science. But in the context of human and environmental health, for regulatory purposes one usually employs the relation $\alpha > \beta$.[18] This allows the number of false positives to be greater than that of false negatives: it is safer to consider a greater number of chemicals as dangerous than really are, rather than declaring some dangerous chemicals as inert or benign (error of second type, β). The two conventions $\alpha = \beta$ and $\alpha > \beta$ have different pertinent ethical bases. Other important EU regulations have strong ethical foundations (e.g. the precautionary principle, the proximity principle, and the so-called 20-20-20 EU Directive[24] whose goal is reducing greenhouse gases by 20%, generating 20% of the consumed energy from renewable resources, and increasing energy efficiency by 20% in the EU by 2020).

The leading call for profound renovation in education was made by the UNESCO which commissioned a study by Edgar Morin, the famous French sociologist.[6] In it he suggests the following seven guidelines for education in our century: 1) detecting error and illusion; 2) searching for principles of comprehensive knowledge; 3) teaching the human condition; 4) our connection with the earth; 5) confronting uncertainties; 6) understanding each other; and 7) considering the ethics for humankind. Point 1 is meant to increase the awareness of catastrophic mistakes in the field of chemistry; likewise, in points 3 and 4 the intention is to raise the students' consciousness and knowledge of the current world emergencies.

This is the one side, the view of the world around us. But also our own position as individual chemists and scientists must be addressed, the way how we operate, how universities and their members teach and perform science, how they (we) are motivated, and how they (we) understand their (our) actions and intentions. This depends to a great extent on our upbringing as individuals, the specific cultural context in which we have been and are living, and many other driving forces, even unknown or unconscious ones. This all plays a role as reasons why individuals may behave (un)ethically.

3.2. Sustainability, the Ability of Perceiving Reality: A Practical Course

A practical approach to such a seminar would consist of four biweekly sessions based on a protocol suggested by J. Wetmore and J. McGregor.[25] The project has two purposes: on the one hand it serves as a kind of prototype for designing and improving ways of bringing ethical questions into the daily lab work; on the other hand, it aims to educate the participants to think about science from a new perspective. As a third goal, this kind of discussion can help uncover values and regulations that are commonly valid, following Habermas' discourse ethics.[26]

The first session starts with the general question "Why did you decide to become a scientist?". Every participant has five to ten minutes to consider his or her answers before presenting them. Questions like "Society has provided the funding for your research: what may society expect you to do with the money? Is it consistent with the ideals you have mentioned earlier?" may be asked to make the participants defend, explain, or reconsider their thoughts. This first session is to give the participants—who usually do not have any education in ethics or social science—an idea, a feeling about nonscientific problems.

The second session starts with the question "How does science influence society?" The participants usually mention a number of positive and negative effects, mostly the consequences of technological achievements. It is remarkable to observe that, without any external input, the participants usually develop two major points of view: technological determinism[27] and social constructivism.[28] Many students suppose that scientists are not responsible for the (mis)use of their findings. The second question "How does society influence science?" is more difficult, but a variety of answers illustrate the strong connections between the two.

The third session should focus on the particular work of each participant. As an example, the implications of research on biomimetic systems and their potential applications for surface modification may be discussed, including questions like "Do you think more regulation is needed? Do you feel safe with what you do?". In one session it was consensus that it is impossible to foresee and control the outcomes of research, and that regulations can be devised only after science has developed to have practical consequences. Mention of the precautionary principle met with loud protest!

During the last session, the participants may work in groups of two or three preparing their own topics. One possible assignment is to write a letter to a commission of experts about an accidental chemical spill and the consequent skin irritation, perhaps a medically unknown phenomenon. This is usually the most controversial session because again the participants mostly do not assume any responsibility for the consequences of their work.

After the last session, a list of questions about the relevance of the course to the participants' work and thinking is handed out, and suggestions for improvement are collected. Different reactions can be expected: some students do not see any relevance to their daily work, others enjoy the new approach to contemplating science and have gained new insights.

The project has been a great success: for the participants, as they learn to talk about chemistry without mentioning molecules, and for the course concept itself. For instance, there are basic differences between "American" and "German" answers, and thus the protocol can be improved for future sessions. The experience gained with these courses suggests that ethical and social aspects are included into natural science curricula; the main reason why scientists avoid considerations about ethics and categorically deny the precautionary principle lies in their lack of knowledge about pertinent concepts and ideas.

3.3. From University to Professional Practice: Taking on Challenges

Upon the conclusion of university studies, it is exciting to graduate and receive a bachelor's, a master's, or a doctoral degree. Now it is time to decide whether to start a career in academia, industry, government, or trade, calling for careful observation of the labor market and its needs. The skills received during university training are assessed according to the expectations of society, the stakeholders, and especially the specific employer.[29] Moreover, society expects a "return on investment".

Employers regularly focus on candidates who fit the requirements of the respective post as closely as possible. On-the-job training is necessary in any case, tailored with regard to efficiency and cost. Differences in interests, sometimes even opposing interests, may occur, and so industrial or professional organizations define moral standards to warrant guidelines for ethical behavior of both sides. The job description must be clear and correct, and at the same time the candidate must be honest in describing his or her skills. Both sides may benefit from a code of conduct conceived by professional organizations for their members. Such rules are helpful in creating a climate of mutual respect.

Companies or organizations prepared to accept such guidelines can offer straightforward contract conditions to their young staff, maintaining or even improving their profitability. This should not be mistaken for quality management! The candidate can show his or her social responsibility and dedication to the common good by doing his or her best and by acting responsibly. When a moral conflict occurs, the persons involved should seek advice from positive-minded colleagues to find a solution by open discussion and sincere support. If the dispute cannot be resolved amicably, a fair parting of ways without mutual damaging may be best. Respect for the reputation of all involved and for a company's legitimate interests must be upheld.

Why is ethical conduct in the chemical profession and industry so important? Owing to the limited understanding of chemistry in society, the moral responsibilities of every chemist and every chemical company should be obvious. This is particularly important in situations when decisions must be taken although there is not enough time or opportunity to follow democratic or administrative guidelines, and/or when appropriate action is possible only with the knowledge of the full context.

In order for chemistry, the chemical profession and industry to thrive, they all must be prepared to act responsibly and with mutual understanding. Paying special attention to the delicate act of hiring and being hired is a most important prerequisite towards this goal. As shown in the next section, continuous and successful industrial practice requires teams that accept and master the ethical conduct.

3.4. Ethics in Affairs of the Chemical Industry

In the past decade, financial scandals in industry (such as Enron in the USA and Parmalat in Italy), doping and betting scandals in sport, and nepotism in politics have created growing public skepticism of established authority and political leadership. At the same time, people's desire for values like transparency and truthfulness has grown.[30] The importance of moral values in every aspect of daily life, also in the business of the chemical industry, is obvious.

Before the Industrial Revolution, ethics was essentially within the ambit of the public morals; later, progress in science and technology and social development added new dimensions. Ethics today is strongly connected to the virtues of responsibility, trust, and credibility, that is, always being fair (playing by the rules), honest, transparent, respectful of the rights and privacy of others, and taking care of dependents. And in industry, other moral values concern the well-being of employees, the interests of suppliers, customers, and the social community, and the protection of the environment.

Research and development in the chemical industry need particular attention because their intrinsic ethical values can have strong influence on the future of companies and societies. Furthermore, the chemical sector is characterized by high health and safety risks, by the potentially strong impact of emissions and waste on the environment, and by company mergers and reorganizations. All this requires an awareness of ethical values, especially during transition periods when employees are subject to a great deal of uncertainty and anxiety. At such times, transparency in communication internally and externally is most important.

Many companies have adopted tools to promote ethical behavior such as business rules, business ethics policies, procurement guidelines, policy statements for health, safety, and environmental protection, rules for the delegation of authority, the protection of employees', employers', and customers' privacy, and guidelines for ethical external relationships including those with public authorities, as well as regulations for quality policy or for the recognition and protection of intellectual property rights. Most organizations attempt to build such a culture of ethics—but not all are succeeding. Employees and managers are needed who understand why such a culture is vital for long-term viability. Business organizations, like people, have multiple dimensions; they need to be developed in order to remain successful.

Some key attributes of an integrity-based industrial organization are the following: 1) employees have a sense of responsibility and accountability for their own actions and the actions of colleagues; 2) the employees freely raise issues and concerns without fear of retaliation; 3) the managers are exemplary in their behavior; 4) the leaders communicate the importance of integrity when making difficult decisions; and 5) they are aware of high-risk situations that could provoke unethical behavior; should it occur, appropriate measures are in place for identification and remediation.

A practical example of how to realize proper ethical conduct was the remediation of contaminated soil and groundwater at an industrial site.[31] Lessons were learned on how to manage the relations and the potential conflicts between several companies operating at the same site to reach solutions, together with the authorities and the public. The problem opened opportunities for jobs and environmental spin-off companies and triggered the development of new scientific and engineering approaches. But it also cast light on conflicts between the owning companies, with the local administration, and with other stakeholders such as public-opinion leaders, newspapers, trade unions, workers, and environmental parties. Discussions about the priorities of remediation versus industrial development and about the proper interpretation of the law took place. In the end, solutions were reached based on the following:

1) industrial commitment to pro-active submission of practicable solutions, beyond the mere application of existing laws;
2) design and implementation of a territorial master plan as a tool for smoothing conflicts and allowing the industrial activity to continue;
3) creation of a climate of trust among all parties involved;
4) transparency of the whole process through establishment of a master of science course in cooperation with the local university (University of Ferrara).

A groundwater remediation project based on the initiative of all the companies on the site was agreed upon and performed jointly, with the nomination of one project leader and a clear mandate to one unit to represent the entire group.

In the course of these activities the industrial partners learned that: 1) further development depends upon the availability of expansion areas; 2) site remediation should be ranked as a high priority and managed as an industrial capital expenditure project; 3) industrial development must be compatible with site remediation programs. The public and the authorities learned that: 1) site remediation is assured by the continuity of industrial activity and that 2) any new projects at the site improve the chance of remediation to take place within a reasonable time.

The goal of maximum short-term profitability, the excessively high ambitions of top managers, the lack of ethics in controlling activities—all these features damage the common good and retard social and economic development.[32] For the common welfare, each individual—also in industry—is called upon to follow values such as solidarity and sincerity, dedication, a strong work ethic, and the sharing of experience and knowledge by continued training and education.[33]

Sometimes there may be lack of resources or ideas, but more often there is lack of trust and credibility among parties! Trust is the critical ingredient of success in many activities—but trust must be given voluntarily. Ethical behavior, thanks to mutual trust and credibility, makes it possible to reduce the cost of transactions, to lower risks, and to provide more value to the economic activities.

3.5. Applied Ethics: A Sustainable Perspective for Young Academics in the Congo

Another test case is whether we are prepared to assume responsibility for the current state of the world, aware of the fact that colonialism, its exploitation and exacerbation of social weakness and injustice existing already before colonization, has led to what is found today in many poor parts of the world. A procedure for dealing with these problems has been advocated before[34]—now practical steps should be taken.

Most universities in tropical Africa presently face severe problems such as the shortage of financial resources, inadequate infrastructure, a large student body, poor research conditions, and ineffective management. Nevertheless, many staff members of such institutions have expertise in their subject areas. But the conditions of research and teaching are difficult and do not motivate young students to consider academic careers. Teaching is mostly based on results obtained elsewhere, and because of the lack of financial resources and the evaporation of some of the international subsidies in networks of corruption, a serious and visible research tradition is difficult to establish. The severity of the situation is aggravated by the massive drain of qualified scientists. In order to keep promising young academics in such countries it is essential to create islands of excellence to give them the home, the courage, and the skills for fair competition. A new generation of motivated young people is needed who are able to contribute to the social, political, and economic development of their countries.

Higher education and research have long been neglected by governments and donors in favor of basic education,[35] which equips people to become workers and consumers. Giving higher education and the training of critical thinkers and scientists equally high priority is more expensive and requires greater care. High intellectual skills undoubtedly are based on a solid education. And the responsible teachers should be from the same countries as the students because they must be familiar with the habits, customs, and cultural and personal background of their students. On the other hand, in a "sandwich" type of program the students benefit from northern affluence and competence in master's and PhD programs. Although it is expensive to set up common curricular standards, this would enhance the sharing of competences, strengthen self-sufficiency, initiate bilateral and multidisciplinary projects, and help in building networks.

Such a project is pursued by two of us (G.B., K.N.I.) in the Congo in cooperation with V. Mudogo and his colleagues. The goal is to establish a partnership program between the University of Würzburg and the University of Kinshasa (UNIKIN), previously of Léopoldville. It was founded in 1954 and was one of the leading universities in sub-Saharan Africa. Young people from many countries, even from Europe, came to study in "Kin la Belle" (beautiful Kinshasa).[36] But the UNIKIN has suffered seriously from the difficult political circumstances of the past decades. Today the buildings, the instrumentation, and the library are in a critical state. The social and economic situation of the academic staff hampers research and teaching. More severely, there are few opportunities for graduates to continue in proper academic or professional careers. All this forms a vicious cycle that prevents the advancement of intelligent, creative young people in a country so rich in fertile land, minerals, and biodiversity.

The excellence scholarship program BEBUC launched in early 2008 is the heart of the project. It is meant to identify excellent students and help them to study in depth in the Congo, then to go abroad for advanced master's studies and/or PhD programs, and to come back to be the professors and leaders of tomorrow. The students are supported—person-to-person—by more than 20 private sponsors from Europe, the USA, and Africa. The sponsors also act as partners and consultants to the students, and even help them settle back in Kinshasa after their studies abroad.

The first building block is the support of bachelor students, who are identified in a competitive, but transparent and fair evaluation process by means of short lectures by the candidates and their examination by an international panel of reviewers. In the exploratory *Pilot Phase I*, chemistry and pharmacy were taken as subjects. Four outstanding students were identified, and in a formal ceremony they received their scholarship certificates in the presence of the Steering Committee of the UNIKIN, the Minister of Education, the representative of the German Embassy, and the Mayor of Kinshasa. At the same time, they were given the status of guest students of the University of Würzburg with free access to the electronic library. At the end of this phase, the students were re-examined (this time in English, no longer in their "native" language French!) and, as their study results were excellent, their stipends were extended (one of the candidates holding a typical examination lecture as a "chalk talk" is shown in Figure 1).

From April 2009 onward (*Pilot Phase II*), ten scholars were supported, and from August 2009 (*Pilot Phase IIb*) 16 scholars. From April 2010 (*Phase III*), additional support from the private Kröner Foundation made it possible to open the system to all academic subjects, presently with more than

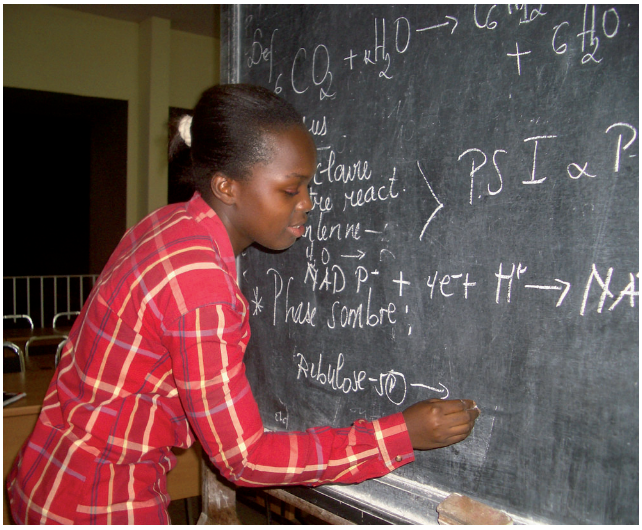

Figure 1. A candidate, here a student in biology, during her 10 min examination lecture.

30 scholars. The scholars now profit from a better infrastructure, with tutors, a secretary and office, and a large seminar room with computers and other equipment.

The second building block of the BEBUC system is the master's program. This is meant to take place preferentially with another African university so that the students can learn to solve problems in the African context, thus strengthening their African identity.

The third block will enable the graduate students to conduct their PhD research at excellent universities abroad, desirably again in joint (sandwich) programs. After many years of undervaluation of Congolese students in international PhD funding programs it is now time that such organizations again accept applications from outstanding candidates from the Congo.

The fourth—and decisive—building block will be to facilitate the students' re-entry into the Congolese universities. Hard work is required to provide acceptable conditions and to assist young scientists in returning to their home country. As a first step, a young pharmacist working in the field of bioactive plants against helminths is now being supported by a re-entry grant from WHO/TDR, a special program for research and training in tropical diseases.

After the promising results in Kinshasa, the scholarship system is now being extended to the Université Catholique du Graben (UCG) in Butembo in East Congo. There, a *Pilot Phase I* was launched in 2010 with two outstanding students of medicine. UCG, in contrast to UNIKIN, is a small, private, new university with about 1300 students and a limited number of subjects. It is the intention to gain experience with two very different institutions and to optimize the BEBUC program to before expanding it other universities.

We firmly believe that this system can be a model for the rekindling of excellence, not only in the Congo but also in other African countries, of course with adaptation to the regional needs and circumstances.

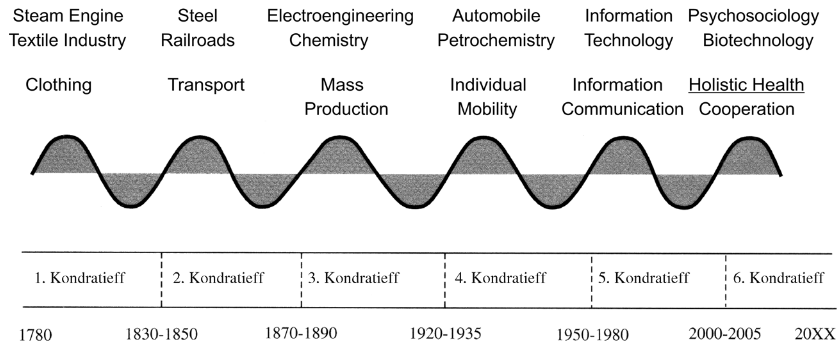

Figure 2. Main technological driving forces and derived social benefits during the past and for the future Kondratieff Cycles (adapted with agreement of the author[37]).

4. Summary

These are just a few examples of how caring responsibility in the (chemical) sciences can be realized in education and professional practice; many others are possible. Moral values are always changing and changeable, depending upon the philosophical background and popular convictions of the time, the social and political conditions, the country and its economy, its climatic and geophysical situation, the wealth and influence of social groups, profession, gender, upbringing, and even the idiosyncrasies of influential individuals. But beyond these highly variable conditions, there is the deep-seated longing for the balance of a peaceful and unhindered expression of the individual in a benevolent society, with a fair give and take. As Bertrand Russell pointed out more than half a century ago,[37] science and technology confer power to man to become less dependent on his environment, but with the dilemma that science and technology disfavor individualism since they require well-ordered structures. In fact, Russell regarded philosophies inspired by science as philosophies of power in which aims and goals are forgotten. His suggestion for an antidote was to adopt a new philosophy in which the solidity of the Roman Empire and the spiritual idealism of an Augustinian or Franciscan theocracy are combined. Other world regions and cultures may find equivalent solutions.

It can be anticipated that many difficulties and fears must be overcome on the way to a human global community at a higher level, not only for the "golden billion". On the other hand, it can be predicted that countries and societies that stay behind or even undermine such deeply democratic processes of developing an empathic-ethical culture at all levels of leadership will remain disadvantaged. As was the case with the move towards a global ecological understanding triggered half a century ago by Rachel Carson[38] and others, those countries and societies that take up the challenge early and face the requirements of a modern, responsible practice of science and technology will fare best—even if, as at the beginning of the growing public environmental awareness, there may be great moaning about the impossibilities and costs of such programs. Those who early implement educational programs towards an equitable and fair human environment at a higher level of cognition[39] will thrive best and reach a new cycle of economic and cultural growth, as suggested by the economist Leo Nefiodow (Figure 2); those who do not, will lag behind. The aim is to spread what is rightly called "applied hope" among universities and educational institutions.[40] With the help of space science and technology, we can easily visualize that we are all sitting in the same boat; let us develop more common sense to avoid wreckage.

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