Priorities for a sustainable civilization

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1 author:

Helmut Burkhardt
Ryerson University

PRIORITIES FOR A SUSTAINABLE CIVILIZATION [1]

Helmut Burkhardt
Department of Physics
Ryerson Polytechnic University
Toronto, Ontario, Canada
M5B 2K3
Email: burkhard@acs.ryerson.ca

Abstract

What are the vital issues facing humankind? It appears that many of today's relevant issues are too big to be understood by knowledge from a single discipline, that they reach beyond the boundaries of individual nations, and that they last for many generations. Who can address these issues? Most political systems have a 5 year time horizon, and focus on national concerns. Our traditionally specialized, discipline oriented education is narrow, and fails us in coping with 'wide' problems. Can we find universal knowledge tools that match today's complex problems ? Can we develop a wide-angle scientific world view to see the whole?

An inventory of some of the Earth's essential resources is presented on a per capita basis. The processes of change are analyzed with respect to long-term sustainability. The major problems facing humankind are listed, and ordered according to priority. Several scenarios are sketched. Goals and means of action are suggested. Ethical and educational issues arising from the need for solutions are discussed.

Keywords: Global issues, vital resources, time constants for global change, scenarios, civilized conflict resolution, ethics, universal knowledge tools, appropriate education.

Introduction

Humankind's global and long-term perspective is radically different from a local and short term view. An example may serve to illustrate this. A former graduate student of the author at the University of Quebec has fifteen brothers and sisters. His father and his mother both came from large families with 16 children each. Being blessed with such a healthy, large family was 'good' in catholic Quebec. In the global perspective, however, that local blessing creates a disaster: some 300 billion human beings on the globe within two generations. Contrary to our individual instincts, the global view categorically demands a halt to this locally happy proliferation of human life.

Industrialized societies have acquired global opportunities and global problems. Instant communication, easy travel and free trade has changed our world into a connected network. Tensions created at one point are felt in the entire net. High technology methods for gathering and transferring of goods and people permit us to take the sting out of local disasters, and to survive in large numbers. But, as the world population is growing agricultural land is getting scarce, and worldwide food production is falling short of the target. At the same time increasing production of artifacts and the disposal of by products are changing the global environment substantially, and irreversibly. Our planet's ecological system is not intrinsically stable or sustainable. Any mishap in the interacting networks may cause disasters of global scope.

What is the changed nature of today's relevant issues? In the olden days, when the 'potato famine' struck Ireland, the Irish immigrated in relatively large numbers to the wide spaces in North America. Today, if there was a 'rice famine' in India and China, and only relatively small numbers of some 3% emigrated from those countries to Canada, that would quadruple the Canadian population, and fill Canada to the carrying capacity of her crop lands.

Normally, we are concerned with local problems, and with topics of our own discipline. The deception of such a narrow perspective is illustrated in the story of the blind Indians describing an elephant. Each one of them has a true partial impression of the creature, but their impressions differ vastly, and they cannot agree on the nature of an elephant. Scientists and engineers judging a global problem are like the blind persons judging an elephant. Each one has a true impression of part of the issue, but the nature of the global problems of humankind eludes them. The partial truth known to specialists is not a good base for wise decisions on complex, global and long-term issues. Solving, even just recognizing these ‘big’ issues requires a wide-angle view of the world.

Growing technical interest in the ‘big’ issues

The Club of Rome is one of the early professional voices advocating a global perspective. It published its whole world model in 1972.[2]

In 1990 a joint appeal by scientists and religious leaders urged both groups to act swiftly and boldly to preserve the environment of the Earth. They state that the problems we are facing are transnational, trans-generational, and trans-ideological, (and we might add trans-disciplinary), and continue to say that humankind needs a much wider and deeper understanding of science and technology, and a sacred respect for our planetary home. They call for a continuing swift reversal of the nuclear arms race, and a voluntary halt to world population growth - without which many of the other approaches to preserving the environment will be nullified. Some 32 eminent scientists and some 270 religious leaders from around the world signed the document.[3]

A call for action was issued by participants of the IEEE, SSIT 1991 International Symposium on Technology and Society in Toronto. It urges that national and international efforts be directed:

1. *To recognize the primacy of the global ecosystem of which humanity is a part.*
2. *To create a sustainable, worldwide, economic community, which affords justice and equality within the human family and reduces abuse of the biosphere and of society.*
3. *To reduce population growth through the creation of conditions (economic, social and political) which eliminate pressures to have large families.*
4. *To prevent further loss of diversity of species of life by conserving and expanding the wilderness areas of the world.*
5. *To protect arable land and those who work it because it will be needed to grow enough food for the burgeoning population of the planet.*
6. *To reduce energy and resources used per capita, especially in affluent nations.*
7. *To resolve conflicts by peaceful means.*

The 43 signatories to this document are mostly scientists and engineers.[4]

In November 1992 the International Union of Concerned Scientists issued a statement addressing some of the global issues such as the environment, energy, global population growth, poverty, and war. According to it the Earth's people have only a few decades to avert global collapse, and the signatories warn of danger ahead. [5]

> *'We the undersigned, senior members of the world's scientific community, hereby warn all humanity of what lies ahead. A great change in our stewardship of the earth and the life on it, is required, if vast human misery is to be avoided and our global home on this planet is not to be irretrievably mutilated.'*

This document is signed by 1575 concerned scientists including 101 Nobel Laureates. The chairman of the International Union of Concerned Scientists, Henry Kendall states that this kind of consensus among scientists is unprecedented.[6] It is interesting to note what the scientists do not mention in their list of priorities: not a single specialized, traditional discipline topic is in their statement of issues that need urgent attention. The broad issues of human world population, and the environment are foremost on their mind.

Lamenting the politicians' resistance to fund research, a physicist suggested recently that research ought to contribute to the solution of current political issues. Then, the politicians would probably see fit to support the research [7]. He goes on to list the national issues: " ... we need to make better and more rapid progress in many economic and social problems, notably the area of environment, infrastructure, health, energy, commerce and crime." - However, all of the issues are big indeed and far beyond the scope of physics.

Global view of some vital substances and processes

We look at several physical, chemical and life substances to illustrate the present state of the world. Consider the following substance inventory, its change rates, and time constants: humans, other life forms, cropland, rain forests, energy, oxygen.

A global inventory of these substances, and the related rates of change is given in **Table 1.** Most of the data presented are found in the Brundtland report.[8]

People are, of course, the key issue for humans. The quality and the quantity of human life on Earth is the very reason for all our activities. The number of humans is the most crucial parameter in all sustainability discussions.

Presently, the human world population is not in equilibrium with the environment. Population is growing. At the present growth rate it is doubling in 2 generations. The population change is driven by several positive feedback mechanisms: e.g. the increase in population is causing an increase in the reproduction rate, improving medical care and food production in recent years is reducing the death rate. The negative feedback mechanisms such as starvation and epidemics have been reduced. The serious population statistics predict that the world population could reach 12 billion by the year 2050.[9]

1994	X	dX/dt	t_1 /years
Number of humans/10^9	5.4	+0.1	54
number of species/10^6	20	-0.12	170

cropland per person/m^2	1600	-25	64
rain forests per person/m^2	1600	-18	90
oil per person/tons	60	-1	60
oxygen per person/tons	180 000	±3.7	5000

Table 1: *Global Inventory 'X', rates of change 'dX/dt', and time constants 't_1 ' for several vital substances. The time constants are linear extrapolations to doubling of the quantity($dX/dt > 0$), or to zero ($dX/dt < 0$). A short time constant identifies a critical issue, one that needs attention urgently. Human world population, oil and cropland have the shortest time constants of the substances considered, and therefore, they are high priority issues.*

Cropland is our most critical resource. At the present world population level we have about 1 ha of green land per person. Two thirds of it is ranch land that is unfit to grow crops. The remaining one third of a ha of fertile land is composed of 0.16 ha of rain forests, and 0.16 ha of cropland per person on the globe. But, we need .2 ha of fertile land to feed a person by means of sustainable, organic farming.[10] Therefore, the true reason for cutting down of the rain forests is the scarcity of crop land and not the greed of profit hungry individuals or corporations. On a global scale, there is a genuine need for more agricultural land. The available cropland is not sufficient to feed the growing number of people on the globe. See **Fig 1**. The globe's total surface for each living human being is some 10 ha of which 7 ha per person is ocean. The land surface per person is 3 ha; it includes 2 ha per person of hot or cold deserts. Apart from the rain forests, there is no fertile land kept in reserve.

Animal and plant life is precious to humans for many reasons. Each species of life is more unique, and much more intricate than any artifact made by man. Therefore, life should be highly valued. Life forms are also important from a utilitarian point of view. Many species of plant and animal life are used in medicine and food production. While genetic engineering may modify some life forms, it is unlikely to replace the great diversity of the natural gene pool. The world's inventory of living species contains some twenty million items. The natural change rate before man's interference was several species per year. But, at present we are losing up to 0.6% per year, or some 120 thousand species per year.[11] Humans, for quite selfish reasons, should grant ample, unencumbered living space to other life forms.

Energy, contrary to a wide spread opinion, is plentiful. Even without nuclear technology it is possible for mankind to establish a long term dynamic equilibrium using solar energy. The sun supplies some 130 PW to the globe which is at present world population 24 000 kW per person. By comparison, the total power used by people living a European life style is 5 kW per person. The direct conversion of solar energy to heat or electricity is a scientifically, and technically feasible energy option. In principle, scientist and engineers are capable of developing a sustainable solar energy system with ample energy for every one at any foreseeable levels of world population.

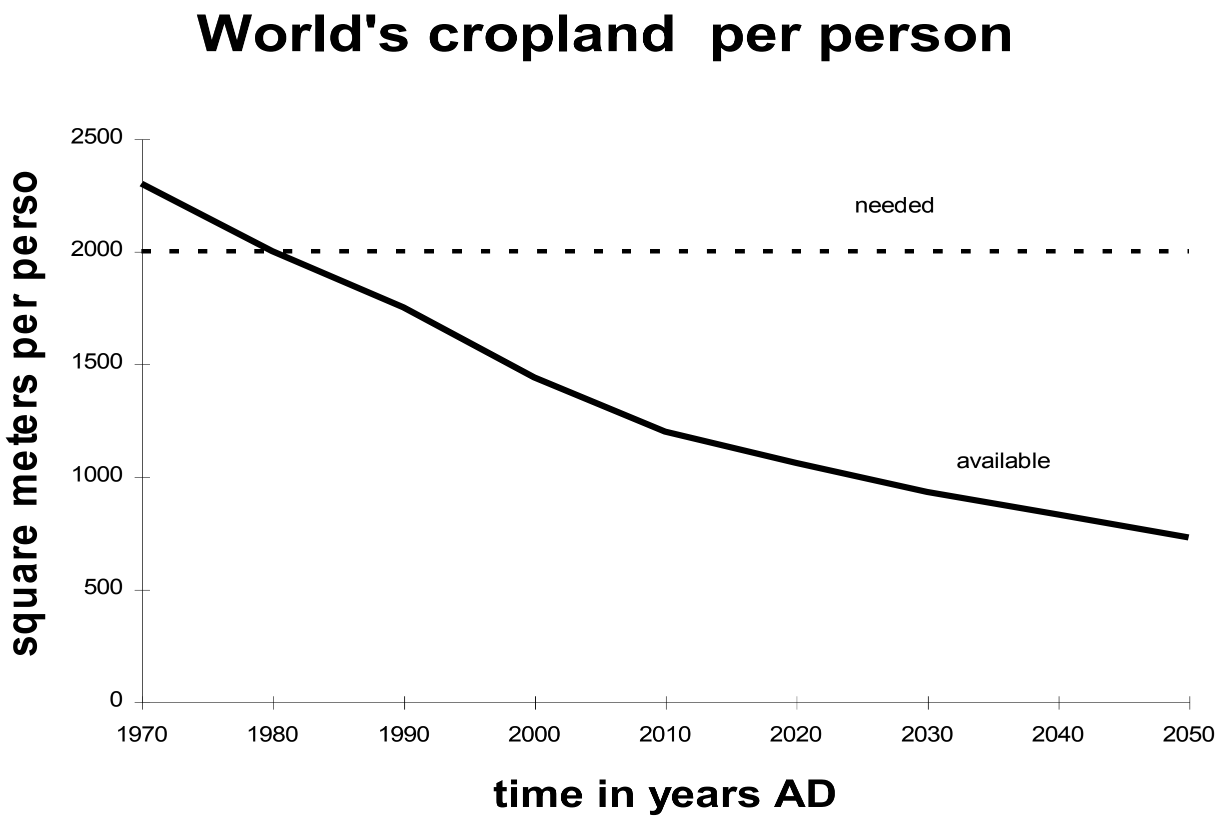

Fig.1: *Globally available and required cropland per person.*
The estimates are based on UN data given in the Brundtland report. The reduction of available land is based on population increase alone. Degradation of soil leads to further reductions of available cropland. From the graph we estimate the time constant for the available cropland per person to be some 64 years. An alarmingly short time to the exhaustion of our food supply! This is a direct consequence of the human population growth.

The direct use of solar energy produces 5 kW with less than 0.01 ha per person, i.e. some 100 m^2 and not necessarily green land. This result is based on assuming an average of 250 W/m^2 of insolation, and a conversion efficiency of 20 %. For the present world population of 5.4 billion people, a square of 730 km on a side would supply 5 kW to every individual. Therefore, direct use of solar energy has great potential for a sustainable future, and it is a challenge for scientists and engineers to make it economically, socially, and ecologically feasible.

Using biomass for generating 5 kW per person is not an option as a basic energy system on a global scale. It requires some 0.2 ha of fertile land per person which is not available, and obviously in conflict with land use for food production. Humankind presently controls 40% to 50% of the net primary production of biomass already[12].

Fossil fuels can't be a base for a sustainable energy system. King Hubbard[13] predicted in the 1950's that cheap oil supplies will peak in the 1970's. Indeed, in a historic, long-term perspective the contribution of oil is minimal, and the curve of oil use vs. historic time is often described as the "Hubbard pimple".

Oxygen in our atmosphere is abundant. A short 'Fermi calculation yields 180 thousand tons or more of it per person, and a production of 3.7 tons per person each year by plants. Even without production the time constant for oxygen is in excess of 5000 years, and one can safely assume that oxygen is not a critical issue. But, carbon dioxide which is coupled to oxygen may well cause problems in the shorter term. Increased carbon dioxide creates a global greenhouse, and global warming. A warmer climate melts polar ice which may lead to wide spread flooding and more humidity in the atmosphere. Most of these effects enhance the growth rate of plants which reduces carbon dioxide in the atmosphere by binding it to the plant material. This multiple negative feedback suggests a stability of the dynamic equilibrium of carbon dioxide levels in our atmosphere.

Scenarios

We are on course towards a human mono culture on this globe. As all mono cultures this is unstable, and prone to a violent collapse of civilization. Recent studies by Kendall and Pimentel confirm an imminent global food shortage.[14] Studies in many countries of the world by T. Homer- Dixon and his coworkers have verified the obvious: scarcity breeds violence.[15] The combination of these two results is frightening. If we fail to control in a civilized manner global population growth we are bound to see a collapse of law and order worldwide. The natural solution to overpopulation is likely to be catastrophic, and a very painful if not deadly experience for many. It may lead to more 'ethnic cleansing' as we observe it in Bosnia or Rwanda. An uncivilized world war could well come from a global food shortage. A much more desirable scenario is the orderly control of world population to sustainable levels, and that ought to be on everybody's mind around the globe.

Action priorities, appropriate knowledge tools

A first step in developing solutions to complex problems is to learn to see the big issues, to develop a bird's eye view of the world. - The Titanic could have avoided the disaster if the captain had been aware of the iceberg in time. Seeing a problem in time is one essential. That is one of the reasons for acquiring a wide angle view of the world.

A second step toward coping with big issues is to develop the means, the appropriate tools to act on big issues. For both, the recognition of, and the action on big problems we require a set of knowledge tools that are wider than what is available in any of the existing disciplines. The revered expert specialist is ineffective, broad wisdom is required. Therefore, a paradigm shift and an educational reform is necessary for us to cope with the big issues.

Aristotle favoured the general and universal over the specific and narrow knowledge. He said: "the wise man knows all things, as far as possible, although he has not knowledge of each of them in detail." " ... for a grasp of the true theory of any universal facilitates the understanding of its specific forms."[16] Today however, a derogatory view of the generalist is common. We call them Jacks of all trades, and masters of none. We need to get away from that paradigm. Comprehensive knowledge is 'good' knowledge. It is necessary for wise decisions on the big issues.

According to Aristotle there are two sciences worth being called wisdom: "... the science of the end and of the good is of the nature of wisdom (for the other things are for the sake of the end). But ... dealing with first causes ... the science of substance must be of the nature of wisdom." The two dimensions of wisdom are illustrated in **Fig. 2**. Comprehensive knowledge of both, the ends and the means is wisdom. If we are to stay in control of our destiny in the face of the global challenges, we must revive Aristotle's quest for universal knowledge that will help us to connect specific knowledge to the current social, economic, political and ecological issues.

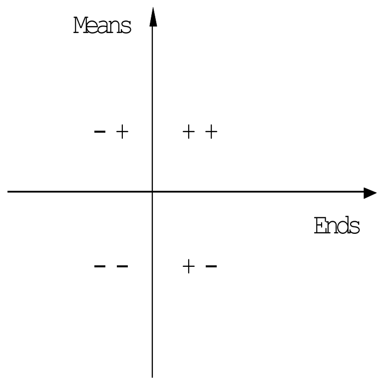

Fig. 2: *Dimensions of Knowledge. The 'Ends' axis represents the ethical dimension. On the positive side lies the common good, the negative represents evil. The 'Means' axis represents the ability to achieve. The ++ quadrant represents the domain of wisdom. It combines good goals and the ability to achieve them. The + - domain pairs good intentions with inability. The - - domain combines bad goals with the inability, it is useless and harmless. The -+ domain represents a dangerous kind of education. It combines misguided or even bad intention with the ability to achieve them.*

The ethical dimension: goal conflicts

Individuals are happy, when they can follow their instincts. However, these personal and momentary values are often in conflict with one's own long term goals, or with the wider social concerns.

Social entities such as nations like to have control over the individuals. In the case of armed conflict with other nations the social entity even expects citizens to sacrifice their own lives for the sake of the nation. This is the extreme conflict between the individual and the social domain.

Nations value economic strength. Today, and in times past a growing economy is a 'good' economy. A growing population stimulates the economy, and is also considered good. This brings the social values in stark conflict with global and ecological values. We have to change our traditional values quickly if we are to prevent global disaster.

For ecological reasons, and in the long term for quite selfish reasons, humankind should restrict the human world population to 4 billion or less. But, for social and political reasons, population control is frequently taboo. There is a serious goal conflict here between the individual's biological instinct of procreation, the social goals for growing economies, and the global ecological concern. World wide and immediate birth control is ecologically desirable for the sake of long term crisis stability.

All these goal conflicts are systemic. They are genuine and real, and must be ethically resolved with fairness and justice in mind for all life forms. It is desirable to resolve these in a civilized way at the goal level, before they become violent physical conflicts. How can we stop the consumerism in the developed nations? How can we stop the population explosion driven by the developing nations? Both are 'bad' processes that foreseeable lead to 'vast human misery and an irretrievable mutilation of our global home on this planet'. We should stop these processes before the global scarcity that they produce lead to global violence.

The genuine goal conflicts make ethics an important component of education, training and practice. Professional associations have codes of ethics that assist their members in dealing with the issue of goal conflicts. The ' Toronto Resolution' is a call for action to scholars and practitioners to find common elements in their value systems. An ongoing work group on ethics in scholarship and science continues the search for trans-disciplinary, and globally applicable elements for professional codes of ethics.[17]

The means dimension: effective knowledge tools

Universality is a feature of scientific tools that has not received much attention in the past. Several aspects to universality need to be considered. Universal validity can be found in the specific and the concrete. Universal coverage, however, is found in the general and in abstraction. The former is well attended to in the traditional scientific and engineering values. The latter has been lost since the Middle Ages, and needs renewed attention in the changed global situation. We need universal tools that enable us to communicate globally, and to act effectively in solving complex problems. What are such universal knowledge tools that should be part of a good education?

All natural languages are trans-disciplinary knowledge tools. However, we have hundreds of natural languages, and therefore, they fail us in effective transnational communication since none of them is globally accepted. Through an act of political will, all nations could teach the same second language at schools and universities. Unofficially at present, English is serving this purpose, but, it has been criticized for its ambiguities, and for the inconstancies in the use of the alphabet. Should it not be possible to create an effective, unambiguous language for global communication?

Mathematics is a powerful transnational and trans-disciplinary knowledge tool. Quite often we discover through mathematical analysis that there are trans-disciplinary structures underlying our disciplinary knowledge. For example, the same differential equation emerges from a mechanical or an electrical problem.

A unified science theory that is based on universal concepts, universal algorithms rather than on disciplinary 'Science dialects' could offer an effective tool for all branches of knowledge. Thermodynamics, transport theory and accounting have the same intrinsic structure, and are good candidates for a universal science theory. Substance accounting has been developed as a knowledge tool applicable in all disciplines and accessible to all people since accounting is a common way of thinking.[18]

Another useful tool in understanding complex systems is J. G. Miller's living systems analogy.[19] Miller observes and describes some 20 functional subsystems that are necessary for any living organism. The 20 elements of living systems include the 5 cooperating parts that N. Wiener originally listed as a necessary minimal complexity that enables a cybernetic systems to seek a goal. Miller's theory offers a basic structure for all technical cybernetic systems such as automata, robots etc. It also applies to social organizations.

The awesome speed of information processing and transfer makes computers and related devices excellent trans-disciplinary and transnational knowledge tools. Yet, the great potential of information technology alone is insufficient to handle the complexity of our global problems. In combination with a general science theory, however, it is an appropriate knowledge tool that enables us to deal with the complexities of an interdependent world.

One of the most potent new tools to change the world is genetic engineering. As all good tools, it also has the potential to become one of the biggest problems that we have created for ourselves through science and technology. Humanists used to say that humans are the measure of all things.

With genetic engineering we are changing the ruler. What used to be fixed, the biological species, now becomes amenable to purposeful change. Man has acquired the means to set goals where previously we could not.

The purposeful manipulation of social structures has a bad reputation in our democratic cultures. The willful change of social units may interfere with the freedom of the individual. Yet, with such problems as unemployment, poverty, famine, and population growth, social engineering may well become a necessary tool. There are, of course, dangers in social engineering as there are dangers associated with any good tool. The appropriate attention to the ethical dimension is a prerequisite for a benign form of social engineering.

Ultimate complexity resides in our environment. The global eco system used to be self regulating. By humankind's intervention the delicate equilibrium has been disturbed. This means that humans are caretakers of the entire 'global garden', and humanity is a further step away from paradise. All nations should set 5% to 15% of cropland aside as nature preserves that will enhance ecological stability. But, most developed nations have none.[20] An illustrative example is Kenya. Today, while Kenya has a population of some 20 million humans, they are pressing their government for the use of wild parks for grazing their herds. Kenya is expected to have a population of 80 million humans in 50 years. What will happen to the wilderness areas?

Eco engineering has become a necessity. A tool to understand complex ecologies has been developed by Howard Odum. He has developed an ecological network theory that allows him to model complex eco systems quantitatively.[21] While Odum's theory still needs refinement, the basic ideas are excellent, and transferable to other applications.

Conclusions

It is important to recognize the global, interdisciplinary, and long term nature of many of today's urgent issues.

World population is the central issue in the sustainability discussion. It has a positive feedback, and therefore, it has the potential for runaway changes. Immediate actions are required for preventing an unstable, global human mono culture. Benign social engineering that is paired with ethics is needed to deal with the big issues. The real task in achieving a sustainable society is the development of a collective will to reduce consumerism, and to curb the world population explosion. The solution requires cooperation of all sectors, the public, the scientific, the religious, the social and the political domain.

Agricultural land for sustainable food production is already in short supply at the present level of world population. Land is the inflexible, critical resource for a sustainable society.

Living space for the many biological species is scarce, and even the small amount that still exists is under pressure to be used for human purposes. Some 5 to 15 % wilderness on the good lands in every nation are desirable for the stability of the global ecosystem. World wilderness projects should be funded by world taxes on regions that have relatively little wilderness area.

Long term solutions for the energy problem are the scientifically feasible direct use of solar energy. Science and engineering can make contributions to a stable sustainable society by making the technology of direct solar energy conversion economically, socially, and ecologically feasible.

A Paradigm shift and educational reform is a high priority for a sustainable society. We need a positive attitude to both, specialization and generalization. Appropriate education means developing good ends in fairness to all, and good means, i.e. universal knowledge tools accessible to all. In order to get results we need a political agenda. Science, engineering, and politics must work together. The United Nations must be reformed and strengthened so as to become an effective agent in global and long term matters.

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