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The Double Helix of Learning and Work*

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Editors' Note

The Double Helix of Learning and Work by Orio Giarini and Mircea Malitza is a report to the Club of Rome first published by UNESCO in 2003. It advances fundamental paradigm-changing ideas in the field of education. Drawing inspiration from the double helix structure of DNA, the authors seek to strengthen the relationship between education and employment in order to bring 'The Knowledge Society' within reach. This article is an abridged version of the second chapter of the report. Successive chapters will be carried in subsequent issues of *Cadmus*.

Chapter 2
The Modular Approach

2.1. Dismantling the Disciplines

Whenever knowledge experienced a boom following a scientific breakthrough or a dramatic assimilation of novelty in society and the economy, a feeling arose that the new acquisitions had to be ordered, controlled, and better organized for more effective use and broader distribution. Looking back, it seems that such moments of stocktaking tended to occur once in every century, always during the first half.

Without going too far back in history, it is possible to suggest that in the Eighteenth Century such a moment of truth was the project of the Great French Encyclopaedia (1750), which was preceded by the earlier English Chambers's *Cyclopaedia...* (1728). The era was that of the Enlightenment that followed Newton's spectacular achievements in science. In the Nineteenth Century, Auguste Comte engaged in a classification of all sciences (1830) in an attempt to cover the entire sphere of knowledge, with the resulting emergence of positivism. He also contemplated the project of an Encyclopaedia that would stand for a "philosophical system of all knowledge in general". The progress of education was also one of his concerns.

In the Twentieth Century, starting from the same premises, the Vienna Circle initiated a daring programme comprising the preparation of a new comprehensive Encyclopaedia (only one volume was published at the time, in 1937) and the establishment of an International Institute of Unified Science (1936). Both projects had to be abandoned right before the outbreak of the Second World War.

It is to be noted that a philosophical approach took pride of place in all these projects. Comte represented the unity of science as a tree (all sciences having a common root). The Vienna Circle saw logical empiricism as the basis of a science that tended to apply a single unifying methodology and to eliminate those branches that they were not capable of being used.

Each of those displays of unlimited trust in the power of knowledge, as incorporated in the sciences, elicited reactions and gave rise to protests. *L'Age des Lumières* was contested by Romanticism. After Comte, the sciences of the spirit were separated from the common trunk of the natural sciences by the "great schism" of Dilthey. Historicism and the axioms of the Vienna Circle were challenged in their very logic by statements indicating the limits of formalization or the untranslatability of language (Gödel, Quine). What should be noted is that crises of overproduction in the sciences generate projects aimed at ordering and classification. It is as if people of vision were looking for systematic methods to store knowledge goods so that those goods could be retrieved easily and rapidly. In the Twenty-First Century, the problem has resurfaced with a much greater sense of urgency. No wonder that it has not waited until 2030 simply to be in harmony with historical experience.

The knowledge boom occurred in the second half of the past century. Its magnitude defies conventional description. Books become obsolete as soon as they come off the press. This phenomenon explains, at least in part, the emergence of thousands of learned journals devoted to a single domain, such as medicine. Even so, no sooner are the magazines printed then research may advance considerably. The Internet has provided a much more rapid vehicle for registering and spreading knowledge. And yet, not even the new science of "information retrieval" has been able to cope effectively with the growing mass of unordered information.

The problem is that classification methods are still rigid and antiquated. They have not changed much with the passage of time. Geometry, arithmetic, astronomy, and physics have stayed, each in one piece, ever since Aristotle. All they did was to multiply by division, but broadly they are the same. During the Middle Ages, universities taught liberal arts in two groups: the *trivium* (grammar, rhetoric, and logic) and the *quadrivium* (arithmetic, music, geometry, and astronomy). Auguste Comte also counted only seven basic sciences: astronomy, mathematics, physics, chemistry, biology, sociology, and ethics.

As soon as a science acquired more advanced methods, it was made into a model. According to the Neurath and the Vienna Circle, the unity of science was suggested by "physicalism". Galileo in the Seventeenth Century and the school of quantitative models in the Twentieth Century chose mathematics. These days they seem to have been dethroned by biology.

> *"The classical education system was dominated by theory. Now, emphasis is being laid on learning through experience and on work-based learning."*

Broadly speaking, the administration of knowledge has been undertaken by individual disciplines for centuries, no matter how diverse and specialized their subdivisions may have become. The disciplines have been institutionalized in higher education institutions: a comprehensive area of knowledge has a corresponding faculty, while its sub-branches are covered by departments and chairs. The university provides a common roof for all and ensures the implementation of legal requirements. It awards graduation diplomas for accepted disciplines that are so described under the relevant law or other act issued by the national educational authority. In some countries, degree diplomas (BA, MA, PhD) in international relations are not awarded. Very few countries award formal degrees in mathematical linguistics or bioelectronics.

Now that the file on the organization of knowledge is finally reopened, it becomes obvious that the approach, based on a strict compartmentalization of disciplines, is the most serious barrier to innovative solutions. Teachers as a professional group display the greatest amount of inertia; they fiercely defend their own disciplines with a dedication that reminds one of the way large predators assert control over their hunting grounds. The classical pyramidal scheme, school-teacher-disciplines-students, has endured for centuries.

It would still be unfair to regard the university of today as a medieval fortress. Spatial unity in a confined sanctuary of learning is no longer the rule. In a modem campus faculty, buildings are often scattered, sometimes even located in different cities. The teaching staff has become considerably more mobile than in the past. Guest lecturers or visiting professors are quite common in most universities. Students move to other countries for a semester and come back with credits obtained from other universities. Optional courses are advertised for those who may be interested in them. During lectures or seminars, students frequently ask for additional explanations on pieces of information they pick up on the Internet. Distance learning competes with day courses. Professors and students alike carry their auxiliary memories in their laptops. Lectures are given using PowerPoint multimedia techniques with visual demonstrations and even musical accompaniment. Mass education has replaced latter-day élitism: universities have become crowded places offering a variety of events, always dynamic and heterogeneous. Informality and casual dress codes are the latest fashion.

At least, that is what one sees from the outside. More importantly, one must note that, on the inside, the university, which used to be the most conservative of institutions of learning, is now engaged in a serious debate on innovation. Myriads of circles, associations, and groups are dedicating their work to innovative teaching and learning in order to absorb the impact of IT. From here to examining the very mechanisms of change there is only one step to take.

Networking has transformed the world's leading universities into a huge laboratory of experimentation, innovation, and change. Which issues are the most topical? The classical education system was dominated by theory. Now, emphasis is being laid on *learning* through *experience* and on *work-based learning.* The traditional school focused on the development of intellect; now, the spotlight is aimed at *skills* and the acquisition of *core skills* or *key skills.*

Such concerns are living proof of the fact that education is moving a step closer to the world of work.

These concerns are announcing further spectacular developments in the Twenty-First Century. Both *experience-based* and *work-based learning* and the rediscovery of the importance of *skills* have been the result of pressing demands from knowledge users in the social and economic environment. Satisfactory answers have not yet been provided. Which disciplines are able to meet those growing concerns? Who is going to teach them? The disciplinary teachers ponder.

The basic tactic that the universities have used in their approach to change is to adopt the new techniques while still retaining the disciplinarity structure. The least problematic were the audio-visual methods that have been on the agenda since the 1950s. Audiovisual laboratories were created, but they served only as additional teaching aids to supplement traditional courses, which remained unchanged. The same happened with the use of television in schools.

The challenge of interdisciplinarity was even more remarkable. A new generation of universities emerged in Europe, in the 1960s, mostly as a reaction of worried governments when confronted with student unrest. The modernity of such new universities was expressed in the first re-wrapping of knowledge. Interdisciplinary faculties and schools were established to cope particularly with complex environmental matters. The response of the universities to the challenge of interdisciplinarity was not the weakening of disciplines but their multiplication. Those new rooms added to the old building "rapidly began to behave like conventional subject departments with the traditional means to maintain boundaries and to discourage the permeability of the staff, students, or resources through them" (Bridges, 2000).

The same tactics were applied to the assimilation of information technology, even though it proved to be more difficult to tame. The computer was viewed as a useful, even indispensable, instrument in educational practice, but still no more than an appendix to the disciplines. That attitude was a mistake. As James Bosco (1994) put it, the new technology does not fit into the old picture as a touch of color, but as an active element that establishes connections with each and every component of the structure, thus altering it. We should remember the words of Marshall McLuhan (1965); "the medium is the message". IT takes a central place among the issues brought forth by the innovative trend in education and learning.

> Increasingly, the Internet is a working space within which knowledge can be co-constructed, negotiated and revised in our time; where disparate students from diverse locations and backgrounds, even internationally can engage one another in learning activities; where collaborative projects can be developed; where communities of inquiry can grow and thrive; and where simulations, models and visually based prospects can be created that allow real interactions within vivid and complex environments that span sensory experiences. [...] Such activities are not just supplements to the classroom experiences; they are unique and irreplaceable learning opportunities themselves; and often they exist only online, not in real classrooms (N. C. Burbules and T. A. Callister, "Universities in Transition", 1999).

There is an item in the innovators' programme that not only provides solutions for the others but also becomes the kernel of the new structure of educational systems: *modularity.* It has the appearance of a most benign and technical methodological approach, but it is the first-ever coherent attempt to break the compact block of the disciplines. Shy and prudent, experimental and local, it has come up with the best way to alleviate the suspicions of disciplinarists: it looks like a mere method to emphasize the individuality of various chapters in a discipline-based course. Modularity actually behaves like the computer: once seen as an instrument, it becomes the generator of total reform.

2.2. Modularization: The Era of Beginnings

Our definition of a *module* describes a unit of knowledge that has:

i. coherence;
ii. reduced dimensions and is easy to handle;
iii. the capacity to be part of a general system;
iv. the possibility to be classified and retrieved from the stock;
v. the ability to combine with other modules and to form a strictly consecutive string with them;
vi. the capacity to provide a content link with the other modules in the string and to provide support for independent learning;
vii. the quality of clearly indicating what other modules have to be consulted in order to assimilate it and to which other modules it may lead
viii. the quality of being selected by the user from several possible options according to an individual strategy aimed at a professional goal or at acquisition of new knowledge (research).

The modules may have different levels of development, most often *(i)* and *(ii)*, but the number of these levels is not limited. Owing to the general and introductory character of the first level, it will register the highest degree of connections and will be resorted to in many variants of the personal curriculum. Interdisciplinary and applied modules follow suit. Here are some examples of modules: "Graph theory" *(i), (ii), (iii), and (iv)*: "Graph theory in the Social Sciences"; "Graph Theory in Management"; "Graph Theory in Transport", the latter primarily involving "Graph Theory *(i)*" or "Graph Theory *(ii)*".

As seems to be the case for all great modern ideas, it is difficult to determine with certitude when and where the notion of modularity actually originated. Having followed with interest the constructivist pedagogical experiments of Weizsàcker (2000) in Germany who used the notion of "bricks", Botkin, Elmandjra, and Malitza, the authors of *No Limits to Learning: Report to the Club of Rome* (1979) wrote: "To encourage innovative social learning, true participation must enable people to open and inspect the 'black boxes' of knowledge, to question their relevance and meaning, and to re-design, re-combine, and re-order them when necessary". They also called for a reorganization of academic structures, "to combine university departments according to issues rather than only and always according to disciplines".

The term, “module”, came to be used in non-formal education, upgrading courses, summer courses, and evening courses, in which, to a great extent, interdisciplinary issues and applications were tackled. Those who organized such courses responded to the needs of the users (industrial units, company managers, etc.) by producing *ad-hoc* packages of modules, each comprising several lessons. Before becoming part of the formal education system, modularity amounted to simply walking around several workplaces along the production line.

The best known and the most dynamic of distance learning universities is the Open University of the United Kingdom. It involves more than 200,000 people of whom some 160,000 are enrolled in programmes lasting three to six years leading to undergraduate or graduate university degrees. Although the need to secure acknowledgement for these degrees still compels the University to observe traditional curricula, the number of innovations is considerable: virtual tutorials, discussion groups, electronic submission of assignments, computer mediated conferences, and more.

The following is a successful sample of a module, or “unit”, as it is called at the Open University: a one-hundred-page booklet comprising two modules titled “Towards a Mechanistic Philosophy, Block 1 I, Units 4-5, Science and Belief: From Copernicus to Darwin”. It is included in the chapter on Arts/Mathematics/Science/Technology as an Inter-Faculty Second Level Course in the History of Science. The topics suggested for discussion, the quotations and bibliographical references, the required comments on excerpts from classical works, the images and illustrations, the scientific rigour and elegant style – all these are qualities that make the two modules examples of excellence.

The turning point for modules was reached when they had to face the established structures of disciplinary institutions. In the current era of beginnings, one witnesses the emergence of a host of varied and uncoordinated experiments. Their goals and languages may still be insecure, but they are all brought together by their avowed intention to build curricula on modules rather than on disciplines.

In all cases, modularization began in the final stage of a given educational programme, at the point at which goals were established. It invariably went backwards, from the complex to the simple, up to the starting level of introductory or basic modules. The occupational profiles pursued by the students (*i.e.,* the answers to questions like “What would you like to be?” or “What would you like to do?”) were the most powerful magnets that caused the modular filings to settle in the map of knowledge. The concerns of those who want “knowledge for the sake of knowledge” would be met by resorting to the numerous terminals indicated as “research” in various fields. There are fewer reservations today about asserting the importance of the profession and its requirements, once educational authorities have set “enhancing employability” as their top priority.

The exploration of the theoretical aspects of the modular approach has been the object of several praiseworthy works. Warwick (1987, 1988) provides a concise definition: “A module is a unit of curricular material, complete in itself, to which further units may be added for the achievement of larger tasks or more long-term goals”. He emphasizes two broad tendencies, one “which begins with the established subject matter of a course” and the other that "takes the students as its starting points". The students would thus build programmes for their individual needs by choosing modules from a larger menu. The next steps are "the complementary approach (no predetermined order, complete freedom of choice), the sequential modules (minimal amount of modular prestructuring to ensure progression towards specified goals), the concentric model (integrity of subject matter maintained through linking modules to a common core), and modular stratification (precise order to be followed). Even the designers can be identified by their different styles.

> Traditionalists, for example, give direction to their work by breaking its contents down into cognitively meaningful sections. Progressives permit students to construct personnel programs from a large number of free-standing, independent modules or even to generate epistemological patterns of their own. The behaviorist shapes the learning process by a gradual progression through carefully sequenced units, rewarding success with a series of credits whilst the devotee of experiential learning looks to modules to rescue creativity from the tyranny of the timetable.

All these distinctions are pertinent insofar as modules, especially in the experimental phase, are created for specific, immediate, or short-term purposes. Most of them originate from the applied, vocational, and technical sector; they are extracurricular and non-formal, especially designed for small and *ad-hoc* tasks. However, when dealing with an all-embracing pattern of formal education, all approaches are valid and non-exclusive. The approach of the main programme combines "core modules" (which are indispensable), direction (even though it may change), personal constructions (that pursue further linkages), and contents sequence constraints together with the advantages of a series of successes that are easier to obtain by taking smaller steps.

2.3. The Double Helix of Learning and Work: A Major Project

While the cumulative and gradual pace of science and knowledge is a datum, there are times when the pressure of problem-solving requires a focused effort, based on a plan and consistent guidance, spanning a long interval of time, and involving numerous research centers and considerable investments. In the area of the physics of particles and of nuclear physics, CERN (Geneva) is one such international center. In recent years, the Human Genome Project (HGP), which was developed in the 1990s, was a most spectacular and ambitious venture. It also had the structure, organization, and other characteristics of a major project.

The Human Genome Project overlaps partially, at least metaphorically, and for the second time, with the topic of this study. At first, the joining of the two complementary helixes – Learning and Work – suggested the double helix structure discovered by James Watson and Francis Crick. In the second instance, both the Human Genome Project and Learning and Work use the same key word to define their stated goal: *mapping the genome* by resorting to DNA markers and *mapping knowledge* in terms of its constituent parts. Both cases involve daring attempts to master complexity.

For quite some time, the human genome has been estimated as consisting of 50,000 to 100,000 genes based in 23 pairs of chromosomes. Two reports published in early 2001 came up with smaller figures (31,000 and 26,000 respectively), but some biologists are still convinced that further research will show that the stock of genes that it took to carry the blueprint for human beings is something between 65,000 and 75,000.

Each chromosome contains a DNA molecule, in which four bases – A, T, G, and C – form opposite couples. The order of the four bases on a strand is what determines the information content of genes, which are nothing but pieces of DNA of different lengths made up of 2,000 to 2,000,000 base pairs. When the project started, only 2 percent of the human genes had been mapped. The chromosomes were numbered, and every time the physical mapping of one of them was accomplished (no. 3 or no. 4), the media hailed the event. In genetic mapping, the idea is to determine the position or spacing of genes on the chromosome, thus obtaining clues concerning those genes associated with genetic diseases. A matrix was introduced into the physical maps. At the beginning, the complete DNA sequence was determined for a virus (170,000 basic pairs). A bacterium has 4,500,000 basic pairs. The human genome consists of 3 billion DNA base pairs, about 1,000 times larger than the bacterial genome.

One might be tempted to say that there is hardly any basis for comparison, in terms of complexity, between the genome and knowledge as expressed in the disciplines that are taught at a university. We still remember the timetables that we used to pin on the wall when we were children. The picture is no longer that simple when we open the course yearbook of a university. Let us take, for example, the *Annuaire général,* Vol. 2, (Faculté des études supérieures de l'Université de Montréal, 1998-1999). The 167 programmes listed there offer more than 6,000 courses (or other activities such as seminars, brainstorming sessions, tests), each indicating the credits awarded. The courses are grouped according to major disciplinary categories, from *Aménagement* to *Art et Science,* to Educational Sciences and Theology, to High Medical Studies, to Music and to Polytechnic studies. The yearbook is remarkable in its attempt to offer optional or *à choix* courses, to focus on practical work and laboratories, to invite lecturers from outside the University, to provide openings towards other fields.

In most universities, such a drive for innovation is at work. Buildings are enlarged or subdivided; new halls are opened, with new corridors to connect them, and wings and laboratories are added. Only the disciplinary structure remains untouched, even though it may now look like a labyrinth.

But, one might argue, will the complexity not increase when a far larger map of modules replaces the disciplinary courses? For a cautious experiment in a technological faculty, 160 modules will have to be introduced instead of 40 courses – four times as many. Since a student has to cover 100 to 200 modules in order to qualify for graduation, the choice of modules is limited by content and sequence constraints. In other faculties, the module/course ratio can exceed a factor of 10.

Moving from disciplines to modules does not amount to discarding the merits of an educational system that has functioned for centuries. Rather, it aims at introducing some radical measures in order to enhance the existing parameters and to improve results. The forty-hour week of a student, now generally divided into twenty-four classes and sixteen hours of individual study, is maintained in reversed proportion: sixteen classes and twenty-four hours of individual study. If we consider part-time or distance education, this proportion is but a minimal indicator. Given the variety of practice in higher education, let us give another example of a comparative diagram. Five courses per semester would correspond to twenty modules. In terms of reading material to be covered, a one-semester course would normally have around 200 pages. A module averages fifty pages. One course would then correspond to four modules. The figures add up nicely.

Complexity only becomes obvious when we take into account the number of distinct itineraries that may be covered in a modular system. Theoretically speaking, there are quite a few ways of choosing 100 modules out of 1,000 that are on offer. Of course, the number of choices will become smaller when we consider the conditioning that is inherent to a network of constraints: access to a module essentially implies covering some others.

The Learning and Work project introduces the second phase of modularity, following the experimental phase. It may take a decade for the educational system to introduce the modular method into this first phase, to build it up to a critical mass, and to become aware of its benefits, which multiply in relation to the growing number of applications. Thus, a large university that offers degrees in both medicine and technical sciences will receive more benefits than a smaller one. And a consortium of universities will score even higher. Also, in the experimental phase, it is crucially important to elaborate modules that are tailored to suit the entire active life scale. Such modules can be offered early on to adult users who either turn intermittently to educational cycles or cover them while working.

The Learning and Work project has as a main goal the mapping of knowledge according to the practical criteria of education distribution and use, learning, and training, for which it attempts to produce a modular sequencing operation. The project tends to cover everything that an individual can and must know in order to perform professions and roles, while also accomplishing the traditional goals of education (personal fulfillment, dignity, productive activity, social roles, conscience).

The Learning and Work map starts at the points at which the educational system transfers individuals to the sphere of work. Those, obviously, are the terminus points of job-oriented education, technical schools, and higher education. However, the map is built according to the principle that an individual can join the sphere of work at any point and then return from the helix of work to the helix of education at any time.

> In an ideal university, as I conceive it, a man should be able to obtain instruction in all forms of knowledge, and discipline in the use of all methods by which knowledge is obtained. In such a University, the force of living example should fire the students with a noble ambition to emulate the learning of learned men, and to follow in the footsteps of the explorers of new fields of knowledge. And the very air he breathes should be charged with that enthusiasm for truth, that fanaticism of veracity, which is a greater possession that much learning; a nobler gift than the power of increasing knowledge; by so much greater and nobler than these, as the moral nature of men is greater than the intellectual; for veracity is the heart of morality (Aldous Huxley, *Brave New World,* 1933).

Still, where is the epistemological debate? It is all about knowledge, and we first need agreement on its definition. It may well be that knowledge can no longer be represented by a single tree. But it then becomes a forest, as each discipline advances according to specific laws. How can one account for the intermingling branches since the roots are distinct? The issue is deeper than such metaphorical interrogations may suggest.

It is an acknowledged fact that the ages-old philosophical questions regarding the nature and uniqueness of science, which defied classification and allowed the answers to emerge from free practice, have a certain justification. One way to produce a comprehensive mapping of science might be suggested, from time to time, by the methodological approach. Another way might be offered by logical criteria. But the need for a practical scheme is so compelling that, at the start of the Twenty-First Century, there is no time to wait for complete answers.

It is difficult to visualize the completion schedule for an enterprise such as Learning and Work in concrete terms. For one thing, global educational authorities do exist. The most active and productive one is UNESCO. Next to it, the International Labour Office (ILO) is equally busy insofar as work issues are concerned. The two of them initiated the EFA (Education for All) programme together with the United Nations Development Programme (UNDP). Regional organizations should be vitally interested in the project. Some also have considerable means such as the European Union and the Council of Europe.

Powerful nations support major education programmes that reach far beyond their borders. The United States, Japan, France, and the United Kingdom have dynamic and open educational systems that can yet play an important part in the launching and development of the Learning and Work programme. These countries can be assumed to be very sensitive to the Learning and Work potential, for their policy statements frequently mention unemployment, the aging of the population, the knowledge economy, and competitive pressures as their major areas of concern.

The envisaged programme largely depends on meaningful international co-operation. Mixed groups of experts with related profiles and then intergroup teams will have to do most of the job. The largest groups will be those on medical, technical, and natural sciences, on economics, law, literature, arts, and other humanities. Those enclaves of experts will keep their doors open to representatives of commerce and industry, public authorities and services, human resources managers, and NGOs. The media will need to keep the public informed. Permanent centers and periodical meetings will examine developments in the area of relevant technologies. The software industry will need to encourage a more extensive use of artificial intelligence methods. The lead partner, or perhaps the owner, of the programme will possibly be a consortium of several ICT companies that are the engine of today's exponential development of this industry. They owe everything to knowledge and training, so they are in a better position to understand their value.

One effect of, and also a condition for, the implementation of Learning and Work will be that of changing most of the existing legislation on education, work, insurance, and social services along with possible constitutional adjustments. Legal experts and legislators will be kept busy for almost a generation. They are likely to take pride in breaking new ground in the development of adequate doctrines and procedures.

The map of knowledge or the module scheme differs from that of the genome at the point where the latter strives to master a set, albeit a large one, of fixed mechanisms. Knowledge, however, is perpetually moving. Among other reasons, modules are created because they can be refreshed. The fact that they will always compete is the best way to keep them awake. Will a student choose a module suggested by his tutor if he can find a better one on the Internet? The observance of certain standards must still be provided by people of acknowledged competence. That is why the administration of the worldwide system of the map of knowledge will require new global institutions. At least three will be needed, not necessarily as central institutions but rather as peer networks: *(i)* to supervise quality: *(ii)* to ensure compatibility with the existing systems; *(iii)* to acknowledge credits.

The evaluation of studies and the issuance of appropriate certification are more complicated tasks, but ones that are not insurmountable for the modular system. The association of the modular system with the system of credits is organic from the very beginning. Without such a link, the cumulative character of learning could not be maintained. There are several crucial points that should not be overlooked: the social value and prestige attached to a diploma or to a learned title; the "label" resulting from a certain type of education, which will eventually stick to one's visiting card and private identity; the avenues it opens into the world of employment and practical activity.

An individual accumulates credits throughout a lifelong learning system. At each moment in life, one does not rely on compact years of study at a precise university or college but rather on the credits that one may have obtained in a genetically indicated direction (engineering, medicine, education, arts, etc.). If during studies that correspond to today's higher education one earns about 300 credits, in the following years, one might earn about 30 additional credits per year, which leads to over 1,000 by the age of 76.

What happens to diplomas? Our suggestion is that for every 200 credits earned, an individual should be awarded a "star". According to that system, a high school diploma would be equivalent to one star; college, to two stars; university, to three; the PhD, to four; further specialization and applications to five or six stars, respectively, and so on. Today's PhD, which entails the obligation to make an original contribution to knowledge, and hands-on experience in scientific research might be assimilated to bonuses. In any case, prestige incentives or rewards should not be inferior to those awarded under the existing system. One of the goals of modularization is to keep alive and to motivate the effort of going a long way toward the acquisition of useful knowledge.

2.4. The Computer as Consultant and Provider

A project that pursues goals of the magnitude of the Learning and Work project could not be imagined or accomplished before the ICT revolution. Without the computer, the mapping of knowledge in the form of learning modules could not be undertaken. The computer provides the necessary programmes for the listing, positioning, and stockpiling of the modules in a huge database. The retrieval and combinatorial techniques are already familiar to most users. But here comes the big surprise! The map of knowledge cannot be represented as a linear text. Commonly used texts and graphics cannot accommodate its complexity. Computer screens can reveal only partially the multitude of the links, and, at best, three-dimensionally. The structuring technique has to be that of hypertext, already used in the building of a homepage.

The map of knowledge has nothing to do with a geographical map one can hang on a wall. Neither is it a projection of some physical area. It is a list of links among entities represented by terms pertaining to each of those entities. The programme provides access to those entities and the possibility to select one and to establish further possible links. The entire process is subordinated to a goal that only the user can determine. The final result of the selection procedure can be represented as a linear or bi-dimensional sequence of modules connected in series or in parallel. This itinerary is the final one that resulted from a succession of numerous selections. Several possible itineraries can be provided as the menus for an ultimate choice. However, even a deliberately final choice is still, in essence, tentative. After going part of the way (one or several modules), the user may revise his or her itinerary and choose new paths.

The technique of the hypertext goes beyond the familiar techniques used in advanced libraries for the indexing of an enormous number of books or scientific periodicals that contemporary readers must consult. If one needs to know which modules refer to a particular issue or use a certain method or even connect to other issues and methods, one will receive one's answer after performing a series of clicks.

What follows is the first sample of a computer at work in the Learning and Work scheme. It draws up a map of knowledge in its own style and then administers it. Since one of the main goals of the system is to create a personal learning itinerary (*i.e.,* the string of modules to be covered), the computer becomes the personal consultant and the monitoring tool of the covering process. The modular path is a twisted one, with many crossroads and turnings. It is not like the disciplinary road, with no turns or side streets, which once embarked upon cannot be abandoned before the final destination is reached. For all the paths that open at the end of a module, the computer is both a guide and an adviser for decision-making.

Meanwhile, the computer demonstrates its effectiveness by searching for, and finding, the basic sources of learning. It opens unimagined possibilities to consult library catalogues and great collections, even to identify the necessary chapter or passage in a book or an article. It is now possible for a student to browse through the rare manuscripts of the Vatican, to search the Library of Congress of the United States, to visit the exhibition halls of the Louvre or the Hermitage, to wander through the Forbidden City of the Chinese emperors, or to climb the heights of Machu Picchu – all from the solitude of a campus room. A laptop is the student's link to global science and to the infinite variety of cultures. The offer is so massive, so prompt, and so varied on the computer screen that the student has to master the art of orientation and selection.

For centuries, students and researchers alike had to work hard to gain access to the sources of learning and to pin down the current state of knowledge so that they could move on. It was common in the old days for students to walk for months before they reached a university in Bologna or Paris in order to pick the brains of a distinguished scholar. Nowadays, updated information is readily available. All one has to do is to obtain the professor's e-mail address. The time-consuming and labour-intensive effort to search for sources has been replaced by the ability to discern the right ones – a superior intellectual quality. The measure of history is given by the progress from the ox-driven plough to the tractor, from the sweatshop to the automated production line, from the horse to the car or the airplane, from sail to steam to diesel. It is also illustrated by the monk writing on parchment *versus* a student reading and writing with his laptop.

When Marshall McLuhan wrote The *Gutenberg Galaxy: The Making of Typographic Man* (1962), he was correct in noting the watershed between a phase of civilization based on the linear and analytical writing of books and the other phase that is submerged in the synthetic and global television image. The immediate inference is that a culture that can use such devices has to be of a different kind, just as the human mind has to function differently in a changed environment. Several decades later, one observes that the written text has not gone out of use; the computer has not caused the total abandonment of paper; and books are still being published. It is only that children now can go to a *médiathèque* (which in France has almost replaced the *bibliothèque)* in the neighbourhood, where they can read onscreen, listen to recordings, and watch videotapes. We have entered the era of multimedia, a splendid mixture of text, sound, and image.

The written text seems to have won the battle after all. The computer has reduced it to a two-symbol succession. The digital revolution has made it possible to mesh sound and image in the same procedure, thus going beyond the analogue techniques. Images have become digital, and so has music reproduction: multimedia is *multi-* only in terms of expression, but it is *uni-* in terms of digital support. Digitalization has made it possible for the main general-use devices to converge: the computer, the telephone, the television set. The miniaturization of information technologies has made all of them portable. It is reasonable to assume that, when competition eventually prevails over the narrow specialization of major companies in the field, a single device will substitute for all of them. When that happens, it will introduce new elements of enhancement into the practice of computer-based learning. The reverse influence is also possible. The new market catering to the Learning and Work system might very well call for new technological and service requirements.

Orbital links via satellite and the hugely efficient optic fibers have caused the information technologies to also become communication technologies. Hence ICT. The past decades have focused on communication, and the improvement process has been subordinated to that particular function.

An immediate consequence has been the emergence of distance education, a new chapter in modem education. It questions the spatial identity of the university. Originally, it was developed to serve the needs of non-formal education that offered adults a form of distance learning using the available media (correspondence, radio, television). In time, distance education gained in efficiency and attendance due to the introduction of new technologies.

Large universities, which had opened far-off branches in the meantime, started to use distance learning as a means of making one and the same course available on several campuses. In Vancouver, Washington (USA), a complete set of distance learning equipment, donated by the Ford Foundation, allows Washington State University to provide courses for a campus in Seattle, almost 500 kilometers away. The 150-university network around the Baltic Sea broadcasts two-hour lectures by satellite, according to an established schedule, to the member universities registered at Uppsala, the headquarters of the Baltic University. In Madrid, a distance university functions according to a regular university scheme of faculties and disciplines.

However, distance education does not go beyond the "school-based teacher learning" formula in the current experimental phase. Even so, it has been welcomed with interest as a variant of the regular university, one in which physical attendance is not required. Universities that have created special distance-learning sections to replace or supplement evening, part-time, or low-attendance courses suddenly find themselves overbooked.

An attempt to define distance learning led to the following list of characteristics: *(i)* modular courses; *(ii)* courses privately funded by students or sponsored by an employer; *(iii)* part-time and flexible study; *(iv)* flexibility of entry requirements and levels of entry; *(v)* diversity of subject range inside degree courses (student-choice); *(vi)* independent but not necessarily student-centered courses; *(vii)* resource-based; *(viii)* limited face-to-face contact with the tutor.

The fact that modularization sits at the core of that list is not accidental. The inadequacy of block-courses in distance communication is avoided by means of the reduced volume and enhanced flexibility of the modules. Example: four major pharmaceutical companies initiated a modularly designed course that can be completed in one to two years on "Structure-Based Drug Design". The complete course runs on the Internet with the aim of creating an "interactive learning community". The students are all enrolled at post-graduate level and are gainfully employed. In Scotland, four universities launched a project on the reciprocal and collaborative authority of tutorial units exchanged via the Internet (MANTCHI – Metropolitan Area Network Tutoring in Computer Human Interaction). Each tutorial had a typical load of one week of work for the student, which corresponds to our definition.

How do students, who have been questioned about the use of ICT in the teaching and learning process, respond? They say they enjoy it. It enhances their responsibility for self-help. It opens new avenues to specialist subjects, to the use of experts, and to the latest scientific data. It broadens collaborative opportunities, and it provides a chance to enable others.

Once the "friendly" machine was created, its performances registered spectacular improvements. Consequently, it is possible to assume that, in the Twenty-First century, artificial intelligence will spread over the vital areas of reasoning, choice, analogy, and metaphor, thus becoming what it is meant to be: a thinking tool that produces reflection, creation, and knowledge. The Twenty-First Century is also expected to witness significant advances in understanding the mechanism of the human brain. What hidden operations of the "black box" lie behind learning processes? Centuries of educational theory and practice as well as long series of learning concepts have failed to greatly enrich knowledge of the mental operations that produce learning. The progress of the machines that assist human learning and a better understanding of the mental processes involved in it will reveal the specificity, potential, and limits of these processes and will facilitate man-machine and man-man interaction.

The resulting learning and work environment will be different from the one in which people operate today.

> The University could also develop models which show the universities solving global issues and problems, not only models which transmit the skills and knowledge necessary to be a global citizen. For example, an interesting model would offer a true vision of what the university can contribute to globalization and the language necessary to make this vision understood and accepted even by those whose major interest is not the breakfast, but the dinner menu preferred by Francis Bacon. In the eighteenth century, an age of exploration and discovery, Buffon, in his *Histoire naturelle,* wrote that the human mind has no limits and that it expands as the universe unfolds before it. Today our minds and our institutions remain strong, in part because of the stimulation of the global inquiry. The Bible reminds us that without vision, the people perish (Proverbs, 29:18). The responsibility for a vision for universities in the next century belongs not only to the students, the alumni, the teachers, researchers, and administrators, but to each one of us. The future is ours to share and to improve by our combined efforts (Roseann Runte, "Globalization and the University", 1999-2000).

2.5. The New Environment of Learning and Work

The United Nations Millennium Summit in September 2000 may have heralded the advent of a new era. The conventional rhetoric that is specific to such solemn assemblies was widely replaced by sound reflection and down-to-earth realism. The debates illustrated the new way in which the international community chose to rank its major issues according to their importance and the amount of anxiety they might cause. The report of the United Nations Secretary-General, Kofi A. Annan, began with three issues of special significance: *(i)* opportunities for the young; *(ii)* employment; and *(iii)* education.

The United Nations acknowledged that globalization "offers great opportunities, but at present its benefits are very unevenly distributed while its costs are borne by all" and that "the central challenge we face today is to ensure that globalization becomes a positive force for all the world's people". Good governance was presented as the only rational way to prevent and to manage the negative effects of globalization. And the very substance of good governance lies in the ability of societies, not just governments, to adapt flexibly to the necessary changes that technological advances have made inevitable. Rather than "adaptable", the word, "prepared", better describes that particular ability to cope with change in the new circumstances.

Education and employment are probably the areas that are the most vulnerable to increasing inequality. According to foresight studies, those areas are also the most exposed to negative developments, were we to pursue the track we have trodden so far. The United Nations report places education and work together. The chapter on employment states that "Education is the first step. Creating employment opportunities is the next". Still, the barriers between education and work are not mentioned. The report does not suggest that the two areas should be addressed simultaneously with a view to providing joint solutions.

The message we are trying to convey in this study is that the next step is to consider education and work together. The Learning and Work approach aims at significant changes in the organization of education and work. In addition to the practical solutions that the new system offers to the two fields, it also enhances the preparedness of society to cope with the challenges of globalization. It is meant to bring an element of flexibility into the entire institutional structure of society, from legislation to finance.

The following combination of features characterizes the system outline:

- It brings knowledge acquisition and its use closer together;
- It provides a unitary vision of life by combining lifelong education and lifelong work;
- It suggests an individual-centered single lifetime Learning and Work strategy, with plenty of opportunities to choose new paths according to one's own evolution and aspirations;
- It shifts the main activity of the university as a manager of discipline-teaching to that of a custodian of module-based tutoring and lifelong learning;
- It offers everybody unlimited chances to enter the system, thus reducing the waste of human resources in the fields of both education and work;
- It enhances the incentives to learning and work, and it proposes a coherent system of recognition based on merits;
- It uses as inputs the most relevant strands of knowledge and continuously refreshes the content of learning, adding the skills and the worldview demanded by modern work;
- It gives to the two main spheres in which human life is spent, learning and work, the possibility to be not only complementary and in harmony with each other but also to stabilize and bring into balance the flow of people moving from one field into another.

All these features are acquired owing to the modular system, whereby units of learning or work have the capacity to combine in a meaningful way. They have connectors for branching inside the learning and working systems, and also between the two systems.

In this process, new professions are likely to be born. The designer of a module is different from its author (a professor, a scientist, or an expert). The planner of modules is different from the designer. Producing modules will become a booming industry, comparable in magnitude with the production of music CDs. The co-operative aptitudes and habits of various institutions and branches and the practice of teamwork and taskforces and of *ad hoc* and temporary synergies will undoubtedly increase.

We have to note that had the corporations had tighter links with higher education, their requirements would have been known and could have generated adequate responses in a system with sufficient managerial flexibility to avoid the rigidity of disciplinary blocks. The corporate universities are now better equipped and financed, freer of constraints, than their counterparts in the regular system, and they can undoubtedly be more innovative and more open to change. Still, are they not, at the same time, liable to enhance inequality of chances? The parent corporations will mostly hire graduates of their own universities, while other graduates will see their chances of employment diminish.

Another attempt to bridge the gap between the enterprise and the educational system was the initiative to create a "university for industry" (UfI). Similar to the Open University, the university for industry accepts total flexibility. It aims to "tell you what learning is available and offer advice if you need it, and provide you with a course that meets your needs, whether full-time, part-time, or through study at home, at work, or at a local center".

At this point, it is quite legitimate to ask ourselves: Should the polytechnic universities not be the industrial universities? Should they not make the changes that have already been assimilated by the industrial university?

In any event, the two initiatives – the corporate university and the university for industry – are clear symptoms of the perceived need to link the two domains of learning and work that are still separated and distant from each other.

For those who doubt the advantages of the Learning and Work project, it may not be such a bad idea to analyze the possible objections or even adverse attitudes to it.

First, scientists might say that, since it is the production of science and not its distribution that matters to them, the map of knowledge is not really necessary because it simply records what is already known. Science is interested in open issues that act as a magnet for the vocational profiles on the educational map. So far as research is concerned, the desired applications are also listed among the goals that would organize the knowledge units backwards. Theoretical or practical problem solving necessitates units or modules that exceed the scope of Learning and Work. The objection is valid and welcome. But it is still socially preferable that, instead of suggesting an alternative mapping, scientists should provide their advanced research modules to all those who are willing to join research activities. This can easily be combined with the present or future profiles of researchers. Scientists may wish to work on a parallel mapping of open issues. Such an attempt was already made by Ronald Duncan and Miranda Weston-Smith (1977) when they compiled and published their *Encyclopaedia of Ignorance.*

Another objection might come from the staff of the teachers of disciplines. Although their reticence may be caused by an immediate interest in keeping their jobs, they have to be listened to when they express concern about declining quality standards and loss of academic rigour or specific ethos resulting from the solidarity of the servants of a discipline. The answer lies in the established fact that the major divisions of knowledge (*i.e.,* the natural sciences, the social sciences, and the humanities; the medical and the biological sciences;

formal sciences such as logic and mathematics; and arts, music, and sports) will continue to provide the guidelines for the formation of researchers and for the first approximation of the areas of vocational profiles. The mathematician does not disappear either as a researcher and a competent author of modules or as a tutor for a large class of modules when mathematics is predominant.

"The systems of education and work are not those systems most naturally inclined to change. Provided they become more flexible and modular early on in this century, they still have a chance not to miss out on the future."

The third category of persons who might have reservations about the modular system is represented by those who warn about the overwhelming responsibilities we may prematurely place on the shoulders of young people. A young person is likely to be faced with the lack of preparation of society itself to function in an environment of greater uncertainty and risk. Much of that situation can be blamed on the bankrupt determinism of the past. The market economy requires alert and mobile people, capable of coping with increasing competition. The image of a young person sitting comfortably under the roof of a discipline as his or her only way in life, complacent and indifferent to the opportunities of choice or change, is being replaced by the picture of a new young person who moves along the channels linking the modules, heading towards a promising star and suddenly changing course as he or she sees another, even more attractive, target. This effort will offer a much higher probability of living a rewarding life compared to the prospects offered by the rigid systems, which are already cracking under the strain of change.

To all of the above, one can add the inertia of those systems in which stability is translated by immobility: bureaucracies, institutions, legislation, and conventional and conveniently smug thinking. Such bastions of procrastination are unlikely to survive the sweeping changes that are being brought about by the new century. Human society discovered the merits of flexibility decades ago. Long before flexible approaches were included in Learning and Work, enterprises were using them in industrial production.

Meanwhile, most industries have adopted the modular method using subassemblies that enter different combinations to produce a broad range of finite products, which can be rapidly harmonized, with the demands of customers. Tailor-made or customized products are now being turned out at mass industrial speed.

The systems of education and work are not those systems most naturally inclined to change. Provided they become more flexible and modular early on in this century, they still have a chance not to miss out on the future.

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