Science and Civilization: Tasks Before the Next Millenium

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Understanding the past is sufficiently difficult; the future almost impossible. The past is all we have to seek clues for the future, and this is partly what I will do.

Today it has become quite commonplace to think of science and technology as dehumanizing and alienating. But, is this intrinsic to the pursuit of knowledge, or is it merely a characteristic of the state of science in our age? Quite contrary to the present, if we go back to earlier periods, even much before the Renaissance, we might witness that technical advances such as innovations in agriculture and the mechanical arts, and the harnessing of new sources of power, dominantly had a *humanizing* effect. These technical advances highlighted the value of human intelligence for understanding and controlling the forces of nature. The world seemed to be humanized by the fruits of the intellect, which helped put humans in the center of things, in contrast with their more mediocre status in the scheme of things throughout the middle ages.

Although I acknowledge the need to do so cautiously, it is worth noting some parallels between the state of present-day institutions of Science and the Medieval Church in Europe. While many religions do have certain humanist elements in their origins, towards the centuries that led to the Renaissance, Church learning had become increasingly intellectual and abstract. Perhaps representing a reaction shared by others as well, the poet Petrarch felt the need for a learning that would better reflect the conflicts and idiosyncrasies of human emotion and imagination. Rather than doctrinal formula, Petrarch turned to undogmatic introspection and observation to obtain insights into the human condition.

Perhaps at the source of the current discontent with modern Science and technology is that despite the tremendous rhetoric of advancement and progress, people still feel that the great problems of humanity seem as insurmountable as ever. Injustice, poverty and inequality, a planet which is about to become polluted beyond repair, and aggression, are only some of the issues in which people feel there seems to have been very little progress.

The present disillusionment with science, and recognition of its dehumanizing and alienating aspects bears more than a shadow of similarity to the case of the Church in medieval Europe. The institution that the Church had become was felt to be stifling to the true essence of religion. Noting that the authority exercised by the institutions of modern Science has parallels with that of the Church of that day, we are led to ask whether these institutions may also fall prey to a dogmatism that may hinder the true quest of knowledge, which is one of the inalienable essences of being human.

According to the historian Braudel, "humanism is always against something: against exclusive submission to God; against a wholly materialist conception of the world; against any doctrine neglecting or seeming to neglect humanity; against any system that would reduce human responsibility... It is a perpetual series of demands — a manifestation of pride."

With the Renaissance, humanism prevailed and attempted to restore the importance and power of humans over the institution of the Church. The Renaissance did not happen overnight, it had a long gestation period. It is to be seen whether the sufferings and turmoil of our century are a sign of another Renaissance in the making.

Most of you have heard of the analogies drawn between the institutions of modern Science and those of religion. Some go as far as claiming that modern Science, with a capital "S," has a similar status to institutionalized religion, complete with its elite class of scientists, its ceremonies, its pronouncements, and its exclusion of alternative paths to knowledge. Its exclusive claim to knowledge is not infrequently compared to that of the European Church of the past.

But just as Renaissance humanism was not necessarily an attack against Christianity—let alone God, the present discontent and reaction against Science has more to do with its institutions and exclusiveness, than the fundamental nature of its pursuits.

Conventional wisdom has it that Science is an open method, and recursively encompasses any possible future advancements. But the point that is often made is that, in modern Science as it is practiced today, the

established legitimate methods of acquiring knowledge exclude the attainment of certain forms of knowledge from the outset. This knowledge is the kind of knowledge desperately sought by human beings in their intrinsic pursuit to become complete human beings. And it is this restrictive and exclusionary character of Science which is increasingly questioned and comes under attack. Just as it was not God or religion itself, but the restrictions and exclusions of the Church which came under attack in the past.

In medieval Latin "knowledge" was *scientia*, and no one had a monopoly over it. From the Latin comes the modern English term *science*. But "science" no longer means the knowledge that anyone has or may have. It certainly does not mean a poet's knowledge, but not even a philosopher's or in fact a carpenter's or mother's knowledge. Usually it does not mean mathematical knowledge. Today, "Science" is a special kind of knowledge possesed by special elites called scientists, obtained by strictly defined methods. Their customs, orders, rankings, and costumes, more than superficially remind the clergy. So it is in this narrow sense that "Science" is found self-limiting, and it is knowledge in the broader and wholer meaning of the original *scientia* that people long for.

I must emphasize I am not at all suggesting that we must necessarily embrace metaphysical or vitalistic concepts to fill this void. The point often made is that we should avoid the error of mistaking the fruits of our narrow reductionist and mechanistic science for the totality of knowledge. Ordinary people know this at heart, even though they may not be able to articulate it and even though they may bow before the power that is present-day Science.

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Task 1	To learn to study and recover the whole instead of the parts
Task 2	To avoid polarizing knowledge and to stress its unity
Task 3	To bend our methods to nature, not nature to our methods
Task 4	To bring science down to the people
Task 5	To pay attention to social inventions as much as technical inventions
Task 6	To learn how to manage the new fractal-global knowledge network
Task 7	To reshape education and research institutions according to the pyramid paradigm

Figure 1: Tasks for the future.

2.1 Task 1: To learn to study and recover the whole instead of the parts

The Church was originally resistant to the claims of science to be an alternative source of knowledge. But eventually, it had to be accepted that when the Scriptures conflicted with scientific truth, the Scriptures had to be interpreted allegorically—in the words of an interpreter of that age—to avoid "the terrible detriment for souls if people found themselves convinced by proof of something that it was made then a sin to believe."

Likewise today, some scientists believe that, since we are no more than a collection of atoms governed by the laws of physics—or recently more fashionably—a biological computer running a complicated algorithm, notions such as free will and consciousness are mere illusions. We may not have access to absolute truth, but it is the case that human beings' perceptions of consciousness and free will are so strong and our existence and societies so totally built upon these concepts that, it is not surprising that deep inside people are disillusioned by science or relate to it only in an abstract and alienated way. Some scientists may tell us we do not have free will, but people certainly feel that they *have* free will, and feel that the burden of resolving this paradox should not rest on their shoulders.

We have made machines, and machines have shaped the way we look at ourselves and the universe. Formerly, we looked at nature and human beings as machines, as mechanical systems. Today, the computer serves as the central paradigm and model for the human being. In order to understand the universe, we have simplified it, but the models and abstractions we have used in doing so have been reflected back on ourselves. We find that we have simplified ourselves, thinking that we are also mere computers running algorithms, and denying that part of us not amenable to such models.

I must reiterate that I am not implying the necessity to invoke metaphysical or vitalistic concepts to fill this void. Rather, we must pay close attention to the incompleteness of presently accepted modes of obtaining knowledge, and to the vanity of Science-with-a-capital-"S" in claiming that people can be thought of as collections of atoms governed by particle mechanics or computer programs running on biological hardware, simply because that is what and only what present-day Science understands and knows how to analyze.

Of course, virtually all scientists acknowledge the incompleteness of our present knowledge and claim openness towards new discoveries, professing that these future developments also belong to "science," and it is indeed this character of science which distinguishes it from—and makes it superior to—other systems of knowledge. But in practice it is quite common for scientists' behavior or pronouncements to contradict this stand. A case in point is the position of some artificial intelligence experts which claim that all human thought processes and behaviors can be explained by algorithms equivalent to those we run on computers. Their strict exclusion of to-be-discovered laws of the physics of complex systems which may support non-algorithmic behavior, which in turn may provide clues to the nature of consciousness and so forth, are hardly compatible with the nominal openness we associate with science.

It must be emphasized that the problem is not with the systematic pursuit of knowledge in itself, but with the institutions and vested powers which surround it. And certainly, individual scientists, administrators or other stake-holders are no more evil or ill-intending than other members of society; the same could be said for the medieval clergy. And of course, few would deny the value of the knowledge modern science has indeed given us. Religous sources had also provided valuable knowledge, regardless of whether you believe these to be divine revelation or merely wisdom of the generations.

The reductionistic-mechanistic conception of science, which reached its high point in the accomplishments of the centuries following Newton, has been challenged strongly in this century. Most recent conceptual trends in science and human thought can be looked upon as reactions to it in one way or another. Until this century, science took as its task to analyze, break down, dissect, and reduce to pieces what it saw in nature, in the hope that when the smallest elementary particles and forces were unveiled, we would have a complete understanding of the universe. As well as the laws governing particles were understood, it left a vacuum as to how systems consisting of more than a few such particles were to be understood, let along humans and societies which consist of extremely large numbers of atoms. Among the early attempts at bringing the whole back together was Von Bertallanfy's so-called *General Systems Theory*, or Norbert Wiener's *Cybernetics*. The slogan was "The whole is greater than its parts." Bolder attempts came later in our century: Fractals, Chaotic systems, Complexity theory, Non-equilibrium thermodynamics, Neural networks and Connectionism, Synergetics. These are some of the fashionable names representing attempts being made to tackle the whole rather than dissecting it into parts. For instance, it has been suggested by the noted British physicist Penrose that certain rules governing complex systems, may have the power to explain non-algorithmic behavior in living beings, and thus open the way to an understanding of consciousness. Many experts in artificial intelligence staunchly deny the very possibility of any such thing.

Feyarabend is one of the more influential writers who has criticized the institutions of modern Science, claiming that Science is not as objective and neutral as it claims to be, and its absolute authority and monopoly is not legitimate. Along with many cultural theorists who stressed the importance of disempowered members of societies, he has suggested that we must be more open to broader meanings of knowledge and means of obtaining it. Attempts to distill truth from traditional knowledge, such as that embodied in Chinese Medicine or certain time-honored Indian traditions or folk wisdom are among other experiments, some of which will doubtless fail, but some of which may lead us to a broader conception of knowledge.

Thus an important task facing us is to open the ways towards recovering the whole from the pieces (figure 1). Towards this end it is necessary to realize that Science as an institution is not immune from dogmatism, and the very power and respect it draws makes it all the more important to examine it critically.

2.2 Task 2: To avoid polarizing knowledge and to stress its unity

Another trend in Western thought which is not unrelated to the above is its tendency to create poles. Indeed, this tradition has presented us with various dualisms (figure 2). Dualisms are found in other cultures and traditions as well, though with a somewhat different bent—a subject I will not digress into here.

Some of these dualisms stand out among the others. That between science and ethics, and that between fact and value are particularly significant. Also of note is that after prolonged conflict and stepping on each others feet, science and religion today have finally receded to mutually exclusive domains (figure 3). Religion gave precedence to science in explaining the material world, whereas science no longer made claims regarding values, whether they were based on religion or otherwise. Whereas this is often posed as a victory of science and human reason, the result has been a fragmentation of human knowledge. Humans cannot exist without values, whether they are devout believers or atheists. The relative weakness of religion in our day and the silence of science as far as these matters are concerned may be thought to underly the cults, pseudo-science, and spiritual reactions witnessed in our century. Most scientists clearly demarcate their area of concern. They are comfortable in dealing with the descriptive, impersonal, objective, and factual, but exclude the prescriptive, personal, subjective, and value-laden. As convenient as such a clear-cut separation is, it does not seem to serve us well in an age shadowed by weapons of mass destruction built with the highest technology, but also requiring

Rationality	Emotionality
Objective	Subjective
Fact	Value
Positive	Normative
Science	Ethics
Secular	Religious
Material	Spiritual
Nature	Humans
Rationalism	Empiricism
Mind	Body
Theory	Practice
Thought	Action
Private	Public
Individual	Society

Figure 2: Dualisms in Western Science.

the most of us in terms of understanding our values if we are not to annihilate ourselves.

Another dualism worth mention is the famous "two cultures" of C. P. Snow: the "positive sciences" on the one hand, and the "arts and humanities" on the other, reflecting further fragmentation of knowledge. Snow emphasized the difficulty of communication between members of these two communities, and the widely different concepts they hold of what is knowledge and legitimate means to obtain it.

Thus an important task we face is to not let these deeply ingrained dualisms fragment our understanding of the world, realizing their artificiality and superficiality, and to stress the unity of humanity and knowledge (figure 1).

2.3 Task 3: To bend our methods to nature, not nature to our methods

Modern Science makes the assumption that there is a real world and that knowledge of it can be obtained by observation. It also assumes that this knowledge is objective and independent of the subject. In making these observations, it restricts itself to those aspects of the world which indeed fit this picture, and also results in a special emphasis on exactness and quantitatively measurable events. It is a quite credible argument that literature has taught human beings more about themselves and their societies than psychology and sociology, but since it is not science, the "knowledge" produced by literature is considered to have an inferior status. It may not be exact or repeatable, but it tells people something they need and want to know. Likewise, in the name of objectivity and exactness, scientists tend to quantify things which may be inherently non-quantifiable. A case in point is human intelligence; the attempt to capture it in a single number called I.Q. has resulted in the rich and multi-faceted concept of intelligence to be reduced to the instrumental definition of "what an I.Q. test measures."

A tale of Nasreddin Hoca, an Anatolian folk hero, sheds some light on the matter. Nasreddin had lost a precious belonging in the barn. Those bewildered to seem him searching instead in the courtyard asked him why he was not searching in the barn but in the courtyard. He replied "I am searching here because it is dark in the barn." Much similarly, science often investigates what it can measure, not what human beings want to learn about. And sometimes, as in the intelligence example, it confuses its own abstractions with reality, mistaking its own operational definition with the truth.

The insistence on exactness and quantification limits the range of subjects amenable to investigation, exluding whole areas of knowledge in which humans yearn for and are in urgent need of better understanding.

The Western tradition owes a lot to the ancient Greeks, but it is worth paying attention to what Aristotle had to say on the subject:

> It is the mark of an instructed mind to rest satisfied with the degree of precision which the nature of the subject permits and not to seek an exactness where only an approximation of the truth is possible.

The need to depart from exactness in the conventional sense features itself in many of the fashionable recent trends in science, such as in Fuzzy set theory, Heuristic algorithms, and Chaos theory. After a long-lasting but only partially fruitful effort in trying to imitate the methods of physics and mathematics, the social sciences have also been recognizing that their strength lies precisely in what they thought was their weakness. Human

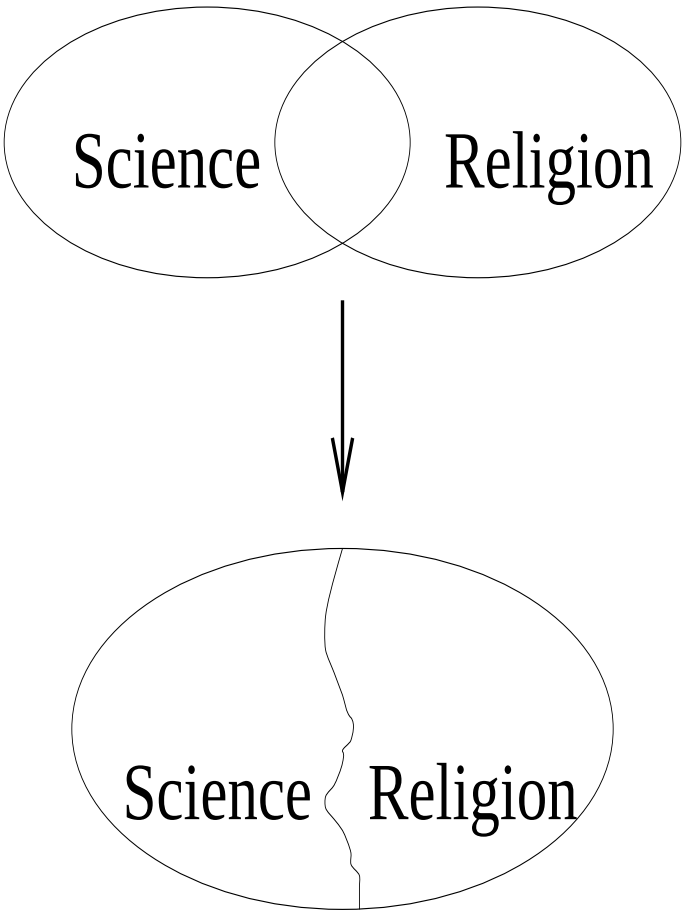

Figure 3: The changing relationship between science and religion.

beings are complex and ambiguos, so any attempt to understand or predict them using precise and well-defined systems is bound to exlude their essence from the very beginning. Thus the methods of social and human sciences, while not being perfect, are perhaps better able to increase our understanding of ourselves. Some go even further, claiming that literature and art, conventionally not thought of as being "Science," are the most illuminating sources of knowledge regarding humans and society.

This leads us to another task, to realize that all areas in which we seek knowledge are not amenable to the methods which have been found successful to date, and that however difficult this may be, we must learn to bend our methods to nature, not to bend nature to our methods (figure 1).

2.4 Task 4: To bring science down to the people

We all know the close relationships between science, technology, industry, and the economy. When people speak of science today, what comes to mind are usually big and expensive projects which have captured the imagination: space exploration, chemicals and pharmaceuticals, electronics and information technology, and the human genome project. As greater and greater wealth is being poured into such research, the discontent felt by ordinary people increases. They are at the same time impressed and disillusioned by the exponential progress, which despite the many conveniences its brings, somehow falls short of solving their *real* problems and providing them the life they long for.

Though quietly, a new concept has been emerging in Europe and more slowly in the United States, as an answer to this dilemma. It is called *community research*. It is contrasted with what its advocates call "Big Science": research heavily funded by governments and corporations and practiced by professional scientists, but which they believe do not serve the more immediate needs of the people. In the words of the Loka Institute, a small organization based in the United States:

> ... community-based research is intended to empower communities and to give everyday people influence over the direction of research and enable them to be a part of decision-making processes affecting them. Community-based research is rooted in communities. Communities often *identify* the issue or problem and participate in *defining* the research question, *conducting* the research, and

finally, *using the results* toward an action-oriented outcome. Our definition of community-based research is: research conducted by, with, or for communities.

We have introduced the concept of community research at Bilkent University, initially to our engineering students, within the scope of a course called *Science, Technology, and Society*. The 160+ students taking this course each year are required to propose and undertake a project of this nature in groups of 8-12 students. Some of the projects they have undertaken are shown in figure 4.

Improving the Life of the Disabled at Bilkent University
Improving Dormitory Room Assignment Procedures at Bilkent University
Evaluation of Nutritional Intake of Students at Bilkent University
Conservation of Energy and Resources at Bilkent University
Improving Course Scheduling Procedures at Bilkent University
Feasibility Study of a Communication Center for University Students in Ankara
A Critical Comparison of University Entrance Exam Systems in Turkey
Factors Affecting Life Expectancy in Turkey

Figure 4: Examples of community research projects undertaken by the community of students of Bilkent University.

Since knowledge is ultimately pursued by people for the sake of people it should be another of our tasks to ensure that common people are actively involved in solving their own problems and that they are knowledgeable enough to have a say in which areas they want public research money to be spent (figure 1).

2.5 Task 5: To pay attention to social inventions as much as technical inventions

The language of modern management books goes a long way in reflecting the spirit of change in out times. "Concentrate on doing the right things, rather than doing things right," is a principle we find between the covers of such books. The advancement of technology demonstrates how much we have progressed in doing things right. Sophisticated (and expensive) medical procedure are awe-inspiring accomplishments. Yet it is not clear whether they add to the greater happiness of a greater number of people as certain neglected (cheaper) public health measures might have.

Society has devoted considerable energy and resources to developing technical inventions, patentable devices and processes in the conventional sense. Compared to the advancements in this sphere, our accomplishments in the area of *social inventions* falls quite short. The checks and balances, stabilizing and efficiency-ensuring mechanisms, and the cohesive and restoring forces of our organizations and societies look ad hoc and primitive and much neglected, when one thinks about the energy and attention we have devoted to exploring and travelling to outer space, to proving the origins of life, or to developing electronic products with millions of transistors even for the most mundane of tasks.

Thus it might be argued that the problems of society itself are much in need of the application of the genius and brilliance which has mostly been directed elsewhere (figure 1).

2.6 Task 6: To learn how to manage the new fractal-global knowledge network

All of the features we have mentioned illustrate that modern Science and technology have excluded certain objectives as well as means of obtaining knowledge. Now I wish to turn to more structural issues with the aim of identifying further tasks.

One of the most familiar trends in science and technology is that of ever increasing specialization. We have all heard the joke about knowing more and more about less and less until we know everything about nothing. A conventional way of looking at this process is by a tree diagram (figure 5a). It is often commented that this process of continual fragmentation necessarily increases the importance of cross-interaction at their interfaces. As conventional scientific disciplines break into several parts, new disciplines which cut across the boundaries emerge. Computer science, control engineering, mechatronics, and optoelectronics are some examples of disciplines which were newly born at the interfaces of traditional disciplines such as mathematics and physics, and mechanical and electrical engineering.

I wish to show you a series of graphs which I hope will underscore a number of key issues in this process. Each dot represents an individual scientist and the knowledge he or she represents. Alternatively, we may think of the dots as fairly self-contained chunks of knowledge. We will hypothesize a beginning in which communication was

scarce and different sets of knowledge were isolated (b). Later, as time progressed, links began to form between adjacent areas of knowledge, but not yet between further separated ones (c). The mathematician might talk to the physicist who might talk to the chemist who might in turn talk to the biologist, but the mathematician would likely not talk to the biologist directly. This state of things corresponding to the conventional compartmentalized academic disciplines persisted into the present century. Then, we entered the age in which the number of links increased beyond adjacent areas, and we are heading towards a situation where links are necessitated between all areas of knowledge (d).

Throughout this process, the intrinsic capacity of a human being has not changed appreciably. Thus, having to form a greater number of links with other disciplines, necessarily made each of these links weaker. Traditionally, a physicist might devote considerable energy to master mathematics, but today he or she must also devote attention to developments in computer technology and electronics, not to mention additional areas such as molecular biology or material science. Paradoxically, *having to know more and more about less and less is accompanied by a need to know less and less about more and more.* Ultimately, since the capacity of a human being remains more or less the same, it is of course the case that the totality of what we can accomplish in a lifetime remains constant. What changes is the structure of the network of knowledge, as reflected by these graphs. If we think of pieces of knowledge as points in a high dimensional space, the scientist of the old had to concentrate on a solid locally connected chunk. The scientist of today can master about the same total amount of matter, but is confronted with the task of mastering a fragmented and finely scattered set of knowledge. It is no wonder the science of fractal sets, which provides a relevant analogy to our state of knowledge, was invented only within the past decades.

The task of a single scientist of today is probably no easier or harder than that of ancient or medieval scientists. But it remains that as a society we face the challenge of learning how to deal with this recently evolved structure of knowledge. An important task for the future is to learn how to manage this new fractal-global knowledge network (figure 1). That we do not yet know how is reflected by our pains of learning. Most scientists today, as well as non-scientists who try to keep up with the world, feel helplessly overwhelmed and frustrated by the amount and diversity of information they must keep track of and master. We sometimes feel nostalgia for the time when scientists casually and playfully pursued their natural curiosity. Perhaps this frustration stems from trying to apply our old habits to the new structure. We feel we must deal with more, but we still strive for the same level of mastery, which is no longer possible. We are psychologically comfortable with knowing very well a small domain, but we are less comfortable with knowing a little of everything. Our hopes are in information technology, which we feel will offer a solution. Of course technology itself is never the answer, but provides the setting in which we are experimenting and through which *we* will eventually find the answers.

2.7 Task 7: To reshape education and research institutions according to the pyramid paradigm

Speaking of knowing more about less and less versus knowing less and less about more and more, one is led to inquire about the proper balance. How much should we know about how much? Clearly it makes sense to know a lot about a few things, but also know a little about many things. This leads me to the hierarchical scheme shown (figure 6). The horizontal axis corresponds to the depth of knowledge in a given area. The vertical axis corresponds to different areas of knowledge. The scientist of the future will have to be very well specialized in a narrow area, represented by the broadest strip at the bottom. He or she will then have to have a still deep level of knowledge in several other areas, and lesser amounts of knowledge in progressively greater numbers of areas, represented by the higher levels in the figure. The highest level should cover the whole range of knowledge including positive and social sciences, and arts and humanities, as well as other kinds of knowledge neglected until know. Beyond being a model for scientists, all people will probably have to be educated or educate themselves according to such a scheme in order to be able to cope effectively with what awaits us.

Thus an important task for the future is to shape our education and research establishments in a manner that helps people attain this pyramid-like structure of knowledge (figure 1). That there is already a trend in this direction is reflected by the growing emphasis on interdisciplinary education and research. The lines to follow in education and science more or less pass through greater emphasis on a broader education and interdisciplinary projects. Just as the arts and humanities and social sciences should form an integral part of every scientist and engineers education, a solid understanding of the physical world and skills in quantitative reasoning should form a part of the education of social scientists, artists, and humanists. The integration of this concept in the sphere of economics, production, and governance may not at first be obvious. In this sphere it may be necessary to broaden the scope of evaluation of private and public activities to include previously excluded considerations. Just as new products and facilities must pass stringent testing and evaluation for

safety and impact on the environment, it may be possible to develop the concept of "social and cultural impact evaluation." Social scientists should be integral members of research and development teams, and society must learn how to shape collective responses to economic activities geared to satisfy their needs and desires. This would encourage corporations to increase this dimension of their activity and devote greater attention to the social and cultural impact of their products. These should be considered an integral part of the product, not an inadvertent consequence, and thus be subject to and governed by the same economic laws of the free market.

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As I mentioned at the very beginning, a time-honored way of looking into the future is looking into the past. When we ask ourselves the question of how technical advances such as transportation, telecommunications, information processing, and manipulation of matter at the level of the atom, will transform our civilizations, it is tempting to look at some of the technical inventions which played a pivotal role in the making of the Renaissance, a period we referred to earlier. Four inventions had particularly important ramifications for this period; they were already in widespread use as the Renaissance took shape, and all of them had oriental precursors. They were the magnetic compass, gunpowder, the mechanical clock, and the printing press. The impact of these inventions are far too diverse to discuss here, but one thing that unifies them is that they all ultimately had a secularizing effect. The compass made possible the discovery of other cultures and religions, weakening the absolutism of Christianity. Gunpowder contributed to the end of the old feudal order and the rise of nationalism, empowering secular forces against the Church. The mechanical clock not only changed humans' relationship to time, it served as the paradigm for the workings of nature, eliminating the need for vitalistic concepts to explain the universe. And finally, the printing press, helped eliminate the monopoly on learning held by the clergy and the dissemination of revolutionary ideas such as the Reformation. Based on an understanding of how these forces shaped the past five hundred years, one is tempted to try to predict how present forces will shape the next five hundred, a task I will escape by postponing to a future occasion.

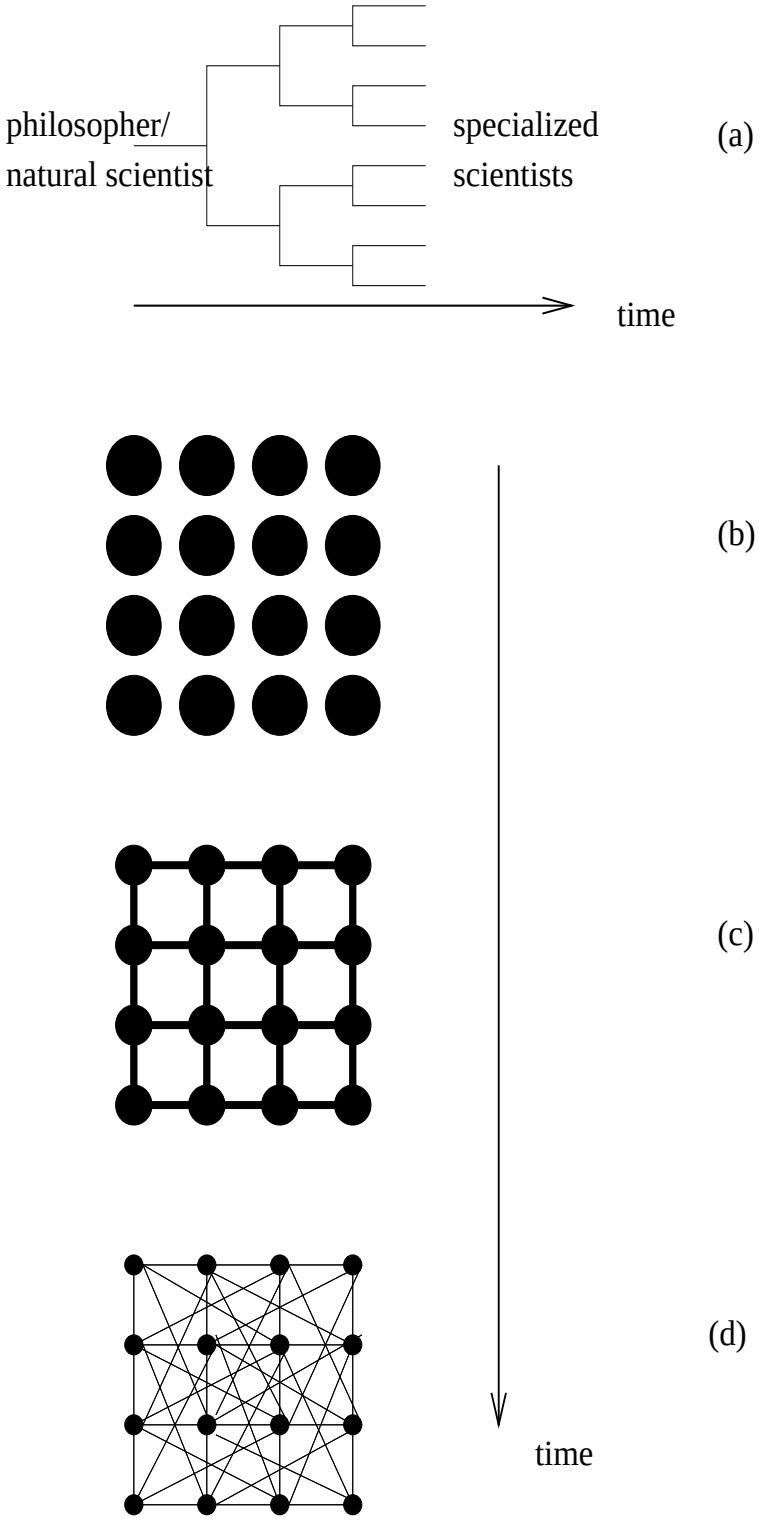

Figure 5: The changing nature of the knowledge network.

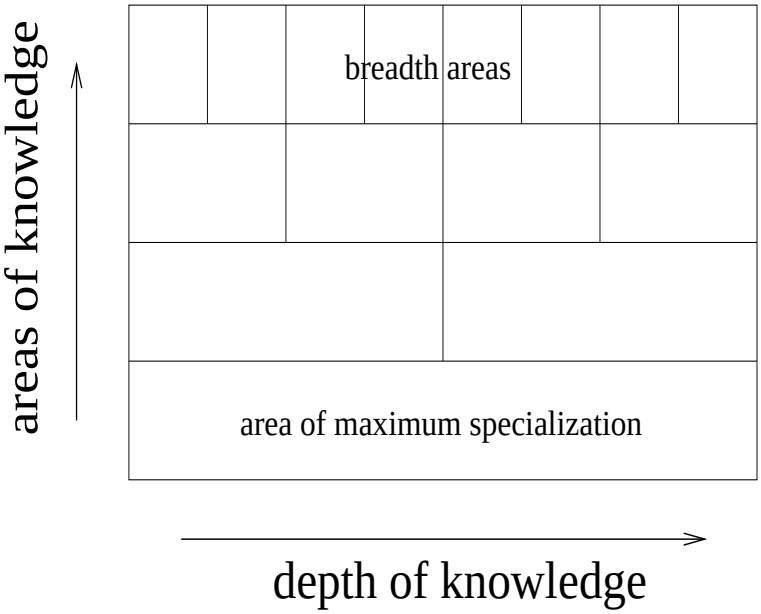

Figure 6: The scientist of the future.