The Formation of a Knowledge Science Institute in Canada—The 1985 Proposal

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Summary

- The formation of a Knowledge Science Institute is proposed with the aim of facilitating the world-wide process of change to knowledge-based economies.
- The Institute will form a network of links with industry, government and universities and facilitate the study, dissemination and application of information on knowledge science and technology and its social and economic impacts.
- The Institute will facilitate the development of multi-disciplinary studies of knowledge science and technology.
- The Institute will undertake system development and application projects involving knowledge-based systems, and train and support others to undertake such projects.
- Knowledge has become a major component of the economy on a par with raw materials and manufactured goods. The production and dissemination of knowledge now accounts for over 50% of the GNP in North America.
- Understanding the nature of knowledge and its social and economic impacts is vital to the development of our industries and our society.
- The study of knowledge is essentially multi-disciplinary and involves all scientific disciplines, the professions and humanities.
- The computer technologies underlying the knowledge economy have advanced at a rate that is so high and has been sustained over such a period that it forms a series of revolutions rather than technology evolution.
- The explosive growth of computer technology from the 1940's may be seen not as a cause of the knowledge society but rather as providing a necessary infrastructure through which to support it.
- The fifth and sixth generation computing thrusts initiated by the Japanese are based on a shift from information to knowledge technologies together with major improvements in human-computer interaction.
- The new generation computing systems will provide knowledge bases that are accessible by people with no specialist computer skills and are integrated into all aspects of the operation of society.
- We are already seeing the effect of this shift in the development of an expert systems industry taking scarce human skills and encoding them for delivery through computer systems.
- A country such as Canada that is rich in resources and able to afford innovation in applications can play a major role in the transition to a knowledge society.
- In particular, the pluri-cultural society of Canada and its good relations with the diversity of other nations makes it possible for it to play a significant role in the world-wide application of knowledge technology.
- The close links with the USA and good relations with Japan and Europe give access to the technological innovations of fifth and sixth generation computing.

Proposal for the Formation of a Knowledge Science Institute

1 Aim

To facilitate the world-wide process of change from manufacturing-based economies to knowledge-based economies.

2 Objectives

2.1 Establish a centre of excellence in knowledge systems.

2.2 Develop understanding of the nature of knowledge, its structure, dynamics and role in human civilization.

2.3 Develop understanding of the process of transition of our civilization from manufacturing foundations to knowledge foundations.

2.4 Develop understanding of the role of information technology in the support of a knowledge-based civilization.

2.5 Develop socio-economic models of knowledge systems and their role in our society.

2.6 Support government and industrial strategic planning relating to knowledge-based systems.

2.7 Facilitate the re-positioning of existing professions and scientific and engineering disciplines to support a knowledge-based civilization.

2.8 Facilitate the development of existing industries to be effective within a knowledge-based economy.

2.9 Facilitate the development of new industries to support a knowledge-based economy.

2.10 Undertake the development of knowledge-based systems of strategic significance for government and industry.

3 Actions

3.1 Establish a physical centre as a focus for study and discussion of issues relating to knowledge systems.

3.2 Establish an international network of those concerned with issues relating to knowledge systems.

3.3 Provide facilities for visitors seconded to the Institute for varying periods of time to study, interact and pursue objectives relating to knowledge systems.

3.4 Provide courses for key personnel in government, industry and university that develop awareness of issues and skills in methodologies relating to knowledge systems.

3.5 Undertake projects that develop resources within the Institute for strategic planning relating to knowledge systems.

3.6 Undertake system developments in collaboration with others resulting in significant applications of knowledge-based systems.

4 Background

4.1 The Knowledge Economy

Knowledge has always been significant to our civilization. However, in the past fifty years this significance has grown to a level where it is coming to dominate other socio-economic factors. Porat made a detailed analysis of the 1967 US national-income-and-accounts and estimated that the information sector accounted for 46% of GNP. Machlup in 1962 drew attention to the major and growing role of information services in the US economy and estimated that in 1958 knowledge production accounted for 29% of the US GNP Porat made a detailed analysis of the 1967 US national-income-and-accounts and estimated that the information sector accounted for 46% of GNP. In these analyses the knowledge sector was seen as growing by about 10% a year in the 1960s. Drucker took this up as a major issue in his 1968 book, The Age of Discontinuity, and estimated that by 1975 the knowledge sector would account for 50% of US GNP. In the 1970s the predicted transition commenced to a post-industrial economy less dependent on manufacturing and human labour, and more dependent on knowledge and information technology.

More dramatic presentations of the socio-economic consequences of the transition to a knowledge economy have been made by Toffler in his 1980 book, The Third Wave, by Dizard in his 1982 book, The Information Age, and by many other information scientists and social commentators. Bell has given a thoughtful economic analysis of expected social change in his 1973 book, The Coming of Post-Industrial Society, and Wojciechowski has analysed the increasing significance of the knowledge product to human society and emphasized the importance of understanding and managing the knowledge ecology. These global models of a changing human civilization emphasize the increasing dependence of the human race on the effective dissemination, use and extension of the store of knowledge. Our over-crowded planet with its diminishing resources can support the still-increasing human population only because we have the knowledge to make efficient use of the resources available.

4.2 Fifth Generation Computer Technology

From the perspective of a shift to a knowledge economy, the explosive growth of computer technology from the 1940's may be seen not as a cause of the knowledge society but rather as providing a necessary infrastructure through which to support it.

Computer technology has advanced at a rate that is extremely high and has been sustained over such a period that it can best be seen as a series of revolutions rather than as technology evolution. Between 1959 and 1980 the number of active devices on a circuit chip increased from one to one million; by 1990 it will reach one thousand million. Over the same period information storage costs have declined to the level where it is now possible to store large encyclopaedias on an optical disk costing a few dollars in a drive that is coupled to a personal computer and costs a few hundred dollars. Every eight years computer technology has advanced in performance parameters by the order of one hundred times. Five such periods of advance may be distinguished historically and we are now in the sixth, termed the fifth generation. For comparison the aircraft industry has seen only one such comparable advance in its 75 year history.

The culmination of the socio-economic pressure to generate technologies adequate to support a knowledge-based civilization may be upon us now in fifth and sixth generation computing systems. The Japanese originators of the fifth-generation thrust in 1981 have emphasized that the major changes expected in this generation will be a shift from information technology to knowledge technology and a major improvement in human-computer interaction. They see the next generation of computing systems as providing knowledge bases that are readily accessed by people with no specialist computer skills and are integrated into all aspects of the operation of society.

The impact of early knowledge-based systems is already apparent in the rapid growth in the past five years of an expert systems industry concerned with encoding the high-level knowledge and decision-making skills of key professionals and making them widely available through computer systems. Initially these systems were expensive and primarily of interest to the petro-chemical, mineral exploration and pharmaceutical industries where expert knowledge in exploratory research is essential to risk-reduction in high-cost ventures. Declining computer costs have made expert systems significant for more routine knowledge and skill dissemination, for example in industries where the retirement of skilled employees is a major problem.

The power of knowledge-based information control systems is nowhere more apparent than through the diversity of activities now possible at a computer graphics terminal. When we see someone working at such a terminal, with the same computer, display and much common software, they may be designing: a computer program to calculate a payroll; an expert system for advising managers; a complex metal piece part; a microelectronic device; a chemical catalytic process; a genetic structure; and so on. What is even more remarkable is that the results of their design can in every case become implemented without further human intervention—the metal piece part may be turned and milled by numerically-controlled machine tools and placed in position by robot arms—the catalytic process may be simulated and then used with no empirical laboratory testing.

4.3 The Role of Canada

The socio-economic importance of knowledge technology can be demonstrated. Computing technologies are becoming available to support the knowledge economy and allow its automation. The pace of change is such that it is difficult to keep up with the new technology and its applications. Whether we actually are in the midst of a revolution or not is a question for the future. For the present, for industry, government, for all sectors of society, it feels like a revolution.

For a country like Canada, that sits between the two economic worlds of natural resource exploitation and high-technology innovation, it is particularly difficult to know how to cope with the technological and social change of the knowledge-based society. We do not have the urgent need to export high-technology products that drives Japanese economic planning. We do not have the requirement of the USA to be self-sufficient in all key technologies. Our balance of trade is favorable due to our rich natural resources. We can afford to import high-technology and make use of it to support our resource-based economy. Our need is to make use of technology to ensure more effective use of our resources and greater added value in their exploitation. We can also increase the stability of our economy by exploiting our increasing skills in the application of technology in worldwide markets.

An emphasis on Canada as an applier of technology does not de-emphasize the need for basic research and development. To develop the skills to use the new technologies we have to provide opportunities to innovate. It will not be possible to understand them fully if we do not attempt to develop them as well as use them. Research and development is much lower in cost than manufacturing and marketing. Its role in developing the knowledge and skills to apply a new technology is just as important as its role in generating products. We need to be foundational and eclectic in our research and then highly targeted in our exploitation of the resulting knowledge.

However, basic research and development alone does not automatically lead to effective use. In particular, knowledge of knowledge technology itself is an insufficient foundation from which to understand its application. The technology is as scaffolding to a building, as an electricity supply to a motor, as pigments to a painting. We have to understand is the nature of knowledge itself and its role in particular applications. Knowledge technology is quite distinct from the computing technology that supports it.

In applications we need to understand both the logic of the marketplace and that of the technology. We must analyse the needs for which society is prepared to devote resources, and the technologies which can shape the world to satisfy these needs. It is the combination of a clear perception of the needs and the effective application of the technology which will determine those organizations and nations which cope most effectively with the transition to a knowledge-based economy.

Canada has one of the most educated populations in the world. Educated people through their knowledge provide the raw material for the knowledge-based economy. We have that raw material but we have to manage it effectively in order to take advantage of our position. We have to couple the knowledge of the technology with that of the marketplace. We must also maintain awareness of the areas of expertise in which we excel and those that we must continue to develop and acquire if we are not to become a third world country technologically.

Canada has sunk resources into information technology that give it the basis for widespread understanding and application of the new knowledge-based technologies based on information control. Computer Science, Information Science and Electrical Engineering Departments have developed curricula and research that make Canada relatively rich in information technology professionals—there is a worldwide shortage and no country is well-off. Natural and Social Science Departments have encouraged the inclusion of computing applications in their own disciplines. Management Science and Industrial Engineering Departments have required computing literacy from their students and incorporated computing in their research. The raw material is there but to exploit it we must come to understand the management of information and knowledge throughout industry, commerce and government.

Computer and communications systems are only tools not ends in their own right. They are neutral to their use and do not supply a model on which to base their application. One can view computing as an advanced technology and look for an application. This is like being impressed by the availability of motor vehicles and trying to see what is the natural direction for them to drive. There is no natural direction for computers either. They will travel on any road formed by an understanding of the knowledge structures underlying the application. That is why the Japanese fifth generation program is targeted on building knowledge bases. We need to encourage students, technologists, market developers, managers and entrepreneurs to think in these terms.

4.4 The Multiple Disciplines of Knowledge

Understanding the nature of knowledge is a topic for several branches of philosophy. In the context of applications it involves the philosophies of science, technology, the professions, and practical reasoning. The applicable techniques are those of logic, of which only the logic underlying mathematics is very well developed. Computer scientists, particularly those working on FGCS are aware of the important role of logic in knowledge-based systems and are becoming increasingly aware of the philosophical problems involved. Philosophers also are becoming increasingly interested in the role of computing as an operational domain for the expression and exploration of philosophical problems.

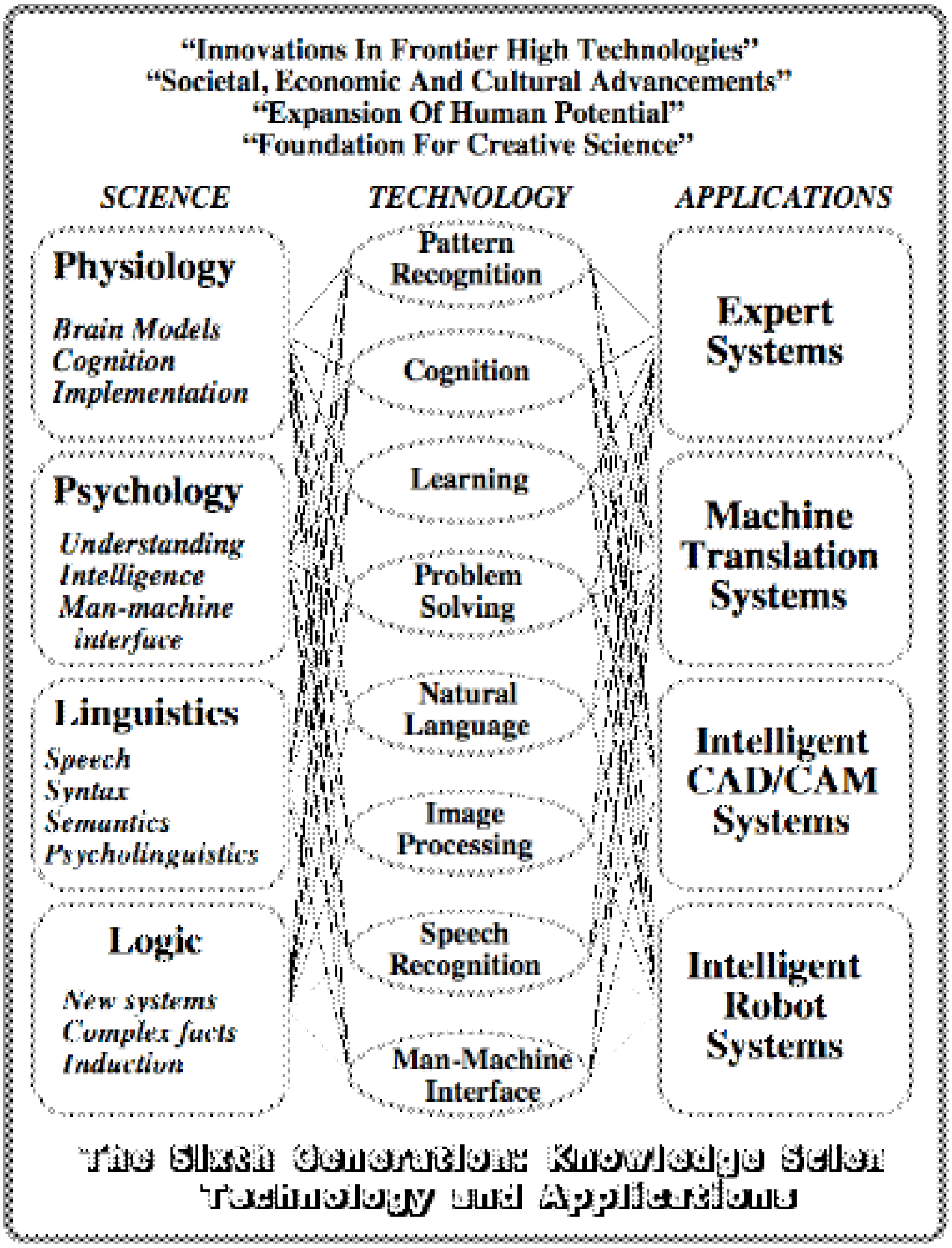
Understanding the role of knowledge in an application is a topic for the scientific discipline and profession associated with that application. Every discipline and every profession will become increasingly involved with knowledge-based technology. This universality presents major problems in the socio-economic management of knowledge technology. There is no natural forum for information collection and dissemination. There is no single discipline that can serve as a focus for most, let alone all, activities.

Computer science is only now becoming well-established as a discipline and is primarily concerned with the development of the technological infrastructure, the scaffolding. Each of the professional disciplines has its own contribution to make to the encoding of the knowledge that underlies it for dissemination through computing systems. Each of the scientific disciplines has the possibility of a new impetus to its own development through the use of knowledge technology. Systems science has an important role to play in providing models for knowledge, its dynamics and impact. The social sciences and the humanities have dual roles to play in that they can make major use of knowledge technology in their own development and are also important to the understanding of its role in our society and civilization.

4.5 Sixth Generation Knowledge Science

These examples illustrate the way in which information technology by-passes disciplinary boundaries and affects all disciplines. We are moving into a world of knowledge science whose foundations are philosophy and system science but whose structure encompasses all our traditional disciplines and professions, and some yet to come. The development of knowledge science in its own right is crucial to the generation of our future industries. This was emphasized recently when the Japanese released their sixth generation computing system development proposals. The translator notes that the Japanese have "coined" the name knowledge science for their new thrust in information technology.

The figure below is a synopsis of the Japanese proposal. Whereas their fifth generation program is targeted on machine architectures using very-large-scale integrated circuits for artificial intelligence machines, the sixth generation program emphasises the knowledge that has to be programmed into these machines. They propose to put together multidisciplinary teams of computing scientists together with neurologists, psychologists, linguists and philosophers, in order to generate the technologies in the centre column for applications in expert systems, machine translation, intelligent computer-aided design & manufacturing and intelligent robotics.



This interdisciplinary program on an international scale is the first significant attempt to operationalize knowledge, making the processes involved overt and giving us knowledge science and technology. It is particularly significant for Canada because the rationale for sixth generation research is that we need to understand more about the nature of knowledge before we can make effective use of fifth generation systems. The applications of knowledge-based systems require interdisciplinary collaboration on a scale never previously achieved.

The key to socio-economic success in this information age is the development of knowledge sciences in their own right—but not as a new discipline. All existing sciences and professions will be transformed by their incorporation of knowledge-based information technology. We need to facilitate this process of change within our existing institutions and industries. We need to promote the exchange and interaction of knowledge across disciplines rather than create new inter-disciplinary "disciplines." In time the boundaries will erode, the scaffolding will disintegrate through lack of maintenance and be dismantled because it is in the way. That will take some time and the transition must be facilitated not forced lest we destroy much of what we value.

There is a need for Knowledge Science Institutes that serve to facilitate the application of knowledge-based information technology. They will bring together many sciences and professions in an attempt to exploit expert systems on a broad front and re-position those disciplines involved as knowledge sciences in which knowledge, expertise, experience and theories are made overt and operational using information technology. At one level they will help to create markets for the new technologies in Canada—at another they will help to put Canadian universities and industry in the forefront of the use of artificial intelligence techniques—at another they will help create a pool of trained students who can aid industry in the effective commercial application of these new technologies.

The USA and Europe responded to the Japanese fifth generation proposals with massive programs of their own. Canada is still discussing its policy in relation to the fifth generation, although the technology is already in place and will be in widespread commercial use by 1988. The sixth generation program with its emphasis on knowledge sciences is vital to our interests as it emphasizes applications. We cannot afford to be slow in entering the sixth generation race. We have the raw material. We have the opportunities. We only need the perception of both and the will to succeed.

4.6 Background Summary and Conclusions

- Viewed in this way, the significance of the use of knowledge technology becomes very apparent.
- The development of the technology itself has to a large extent already happened and will become complete under the impetus already established.
- The new territories and new frontiers are in applications not only to government, industry and commerce, but also to the foundations of our sciences, technologies, and humanities.
- A country such as Canada that is rich in resources and able to afford innovation in applications can play a major role in the transition to a knowledge society.
- In particular, the pluri-cultural society of Canada and its good relations with the diversity of other nations makes it possible for it to play a significant role in the world-wide application of knowledge technology.
- The close links with the USA and good relations with Japan give access to the technological innovations of fifth generation computing.
- We are in a unique position to establish a network for knowledge dissemination to user nations.
- Canada has a major role to play in the development of the knowledge economy, a role that can be played more effectively precisely because we are not critically dependent on the technology itself for our socio-economic future.
- This is the background to this proposal for the formation of a Knowledge Science Institute in Canada.

5 A Knowledge Science Institute (KSI)

The appropriate model for the operation of the KSI a is network of loosely associated people and organizations with a diversity of interests in knowledge science, knowledge technology, the knowledge economy and the knowledge society. The KSI is seen as the facilitator of the development of this network. It should aid the processes of establishing activities, projects and resources in terms of people and funding. It should facilitate these processes in an even-handed fashion, aiding the formation of critical masses of resources, encouraging co-operation, disseminating information, establishing networking. It has an important role to play in the clear expression of the aims and objectives of any particular activity, and the relation of these to wider goals and policies. It should analyse, and aid the analysis of, the consequences of aims, objectives and policy concerned with knowledge but it should in itself be neutral on policy issues.

This model is consistent with the concept that all disciplines and professions have major roles to play in the development of a knowledge-based society. No one new institution would be adequate to subsume all these various roles. Existing institutions will adapt to new roles and the major need is to facilitate this adaption. The knowledge needed to do this transcends disciplinary boundaries and may in itself constitute a new discipline. However, even if there is a new discipline involved, it is one that must learn its own lesson and come to operate in a new way—through a cross-disciplinary network with no particular institutional or geographic focus.

The KSI should be chartered to facilitate the development of many perspectives on knowledge-based societies, particularly where these cross disciplinary boundaries, and particularly where they highlight significant social and economic consequences.

5.1 Structure of KSI

Consistent with the above discussion, the staff of the KSI should be minimal with the key resource being the network of contacts with individuals and organizations having relevant knowledge and skills. The basic organization needed is an Executive Director supported by a secretary and appropriate computer and communications technology in the operation of the Institute, and by a Board of Directors in the formation of policies and strategies.

The Executive Director should have a background that enables him or her to communicate readily with universities, government and industry, and to understand the differing perspectives of their organizations and people. He or she should be familiar with computing and information technology, and should also have a broad familiarity with a wide range of disciplines and professions.

The Board of Directors should be representative of the diversity of interests that the KSI seeks to serve. The individuals appointed should be influential in policy formation for their own sectors and experienced in the management of strategy and change.

Projects undertaken by the KSI should be on a task force basis with a number of individuals and organizations collaborating through a network. Provision should be made for individuals to have temporary attachments to the KSI and to be able to publish through the KSI—it would be appropriate for graduate students to be attached to it.

5.2 Activities of the KSI

All of the activities of the KSI should be consistent with its facilitatory role and its neutrality with regard to special interests. The following list is indicative not exhaustive:

Networking

1) Establish a network of those interested in the knowledge society;

2) Facilitate communication through the network by means of a newsletter;

3) Facilitate communication through the network by means of computer networking;

4) Facilitate increased awareness of knowledge technology and its applications by publishing position papers on significant issues.

Modeling and Forecasting

5) Develop models of the infrastructure of knowledge technologies;

6) Develop models of the computing industry;

7) Develop models of the social and economic impact of knowledge technologies;

8) Use these models for forecasting and strategic planning studies.

Knowledge Studies

9) Undertake and promote cross-disciplinary studies of the nature of knowledge and its role in organizations;

10) Develop models of knowledge generation, acquisition and transfer;

11) Develop concepts of knowledge science and knowledge engineering;

12) Develop techniques for the representation and transfer of knowledge.

Systems Development

13) Collaborate with relevant organizations in the development of knowledge-based systems.

14) Undertake the development of knowledge-based system for significant applications in the sciences, professions, industry and government.

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