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A study of the research and development benefits to society resulting from an international research centre

CERN

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Academic Dissertation

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If you make a theory, for example, and advertise it, or put it out, then you must also put down all the facts that disagree with it, as well as those that agree with it. There is also a more subtle problem. When you have put a lot of ideas together to make an elaborate theory, you want to make sure, when explaining what it fits, that those things it fits are not just the things that gave you the idea for the theory; but that the finished theory make something else come out right, in addition.

In summary, the idea is to try to give all of information to help others to judge the value of your contribution; not just the information that leads to judgment in one particular direction or another.

"Surely You're Joking, Mr. Feynman!"

Richard P. Feynman

W. W. Norton & Company, New York and London, 1997

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Keywords: knowledge, knowledge acquisition, learning, skill, know-how, perceptional approach, organizational learning, technology transfer, the three constructs of social capital (social interaction, relationship quality, network ties), and the two constructs of competitive advantage (inventions, technological distinctiveness).

Abstract

Employing a sample of 411 Finns and 106 Italians who participated in European Organization for Nuclear Research (CERN) scientific programmes during a 10-year Large Electron Positron collider period (1990 - 1999), the author examines knowledge acquisition in a research organization and the knowledge transferred to other institutions to provide answers to two questions. The first question addresses the educational impact of an intergovernmentally funded scientific centre, CERN, for students and apprentices. The second question asks how people's exposure of to an international environment enhances cultural and social dimensions and how society benefits from this exposure. The analysis of technology transfer through people is based on a new model developed by the author combining two different approaches. The first approach is Kaarle Kurki-Suonio's approach, analysing knowledge creation in the learning process, and the second is Ikujiro Nonaka's approach, analysing knowledge creation in an organizational context. In addition, the author analyses the associations between knowledge acquisition, social capital, and competitive advantage for CERN and its users. This is related to a study on entrepreneurial high-technology ventures based in the UK, which examined the associations among knowledge acquisition, social capital, and competitive advantage in young technology-based firms' relationships with their key customers.

Only individuals, not an organization, create and expand knowledge through continuous and dynamic social interaction involving tacit and explicit knowledge, and leading to innovation. Organizational knowledge creation should be understood as a process that organizationally externalizes the knowledge created by individuals and consolidates it at the group level through dialogue, discussion, sharing experience, or observation. Knowledge combined with an individual's value system is the fundamental basis for explaining how innovation occurs.

The results of this research study provide evidence that the social process of participation in meetings, acquisition of skills in different areas and the development of interests by interaction with colleagues are some of the key procedures of the learning process. They show that self-evaluation of the contributions is indicative of the success of the social process in encouraging the advance of both scientific and technological processes to create new knowledge and innovation. Furthermore, the results indicate that knowledge acquisition in a multicultural environment plays a mediating role between social capital constructs and competitive advantage outcomes. Social interaction, relationship quality, and network ties are connected to greater knowledge acquisition, which is in turn positively associated with invention development and technological distinctiveness. For practical reasons, this research is limited to Finland and Italy, but the model of knowledge creation, acquisition, and transfer could be considered as universally applicable.

Much work remains to be done in this area to increase rigor and develop a robust model, but the results obtained are encouraging and useful in understanding the parameters involved in knowledge management and transfer within organizations.

Preface

This thesis summarizes the main results of research activity carried out as a doctoral student at CERN in Geneva (Switzerland) from 1999 to 2002, and at the Department of Physical Sciences of the University of Helsinki (2003–2004). During these years Professors Heimo Saarikko, Kaarle Kurki-Suonio, and Doctor Marilena Streit-Bianchi have supervised me in the preparation of this dissertation. I wish to express my highest gratitude to them for both their intellectual and human contribution.

I thank Professors Salvatore Roberto Amendolia and Jari Lavonen for their preliminary examination, which has been crucial, and I much appreciate the confidence expressed by Professors Jean-Marie Le Goff and Juan Antonio Rubio.

Furthermore, I would like to express my sincerest gratitude for the contributions and ideas of Doctor David Foster, who introduced me to the concepts of knowledge management, thereby enlarging my perspectives to domains outside physics and science communication.

I am also pleased to acknowledge the support offered by Dr Jose Salicio Diez, Dr Julio Oropesa Hernandez, Dr Markus Nordberg, Ms Marika Flygar, Mrs Anita Olofsson, Mrs Tuulikki Pitkänen, and Mrs Christel Ranta for help on administrative matters.

The care and the support received from my friends in Finland, Switzerland and Italy are not forgotten. I thank from the bottom of my heart Pirjo, Elsa, Ellen and Seppo Riihela. I am very grateful also to Irma Hannula, Matti Heikkinen, Christina Helminen, Mervi Hyvönen-Dabek, and Saija Vuorialho for their constant friendship and collaboration. I will never forget the encouragement received during difficult moments from Fosca Aquaro, Valentina Avati, Benedetta Barabino, Emanuela Canepa, Antonella Del Rosso, Monica Gambino, Carla Massaro, Karine Mazza, Lorella Morlotti, Michèle Righettoni, Julie Short, Marco Silari, Tae Takahashi, Keyko Taylor, Donatella Ungaro and Davide Vitè.

Despite our physical distance, I could never have reached the end of this long process without the love of my family. Therefore, it is especially to my parents, Mila and Aldo, to my sister Alessandra and her husband Enrico, and to all the other members of my family, Antonio, Maria, Claudia, Mario, Massimo and Guido that this thesis is dedicated.

Beatrice Bressan

Helsinki, 21 June 2004

List of acronyms

ADMI	**A**dministrative **S**tudent
ARPA	**A**dvanced **R**esearch **P**rojects **A**gency
CASS	**C**orresponding **Ass**ociate
CERN	**C**onseil **E**uropéen pour la **R**echerche **N**ucléaire
CFEL	**C**orresponding **Fel**low
CSTO	**C**omputing **S**ystems **T**echnology **O**ffice
DARPA	**D**efence **A**dvanced **R**esearch **P**rojects **A**gency
DDR&E	**D**irector of **D**efence **R**esearch **&** **E**ngineering
DELPHI	**DE**tector with **L**epton **P**hoton and **H**adron **I**dentification
DG	**D**irector **G**eneral
DOCT	**Doct**oral Student
DoD	**D**epartment **o**f **D**efence
FELL	**Fell**ow
HEP	**H**igh **E**nergy **P**hysics
HIP	**H**elsinki **I**nstitute of **P**hysics
EST	**E**ngineering **S**upport and **T**echnologies
ETT	**E**ducation and **T**echnology **T**ransfer
EU	**E**uropean **U**nion
FC	**F**inance **C**ommittee
HEP	**H**igh **E**nergy **P**hysics
HTML	**H**yper**T**ext **M**arkup **L**anguage
ILO	**I**ndustrial **L**iaison **O**fficer
IP	**I**ntellectual **P**roperty
IPR	**I**ntellectual **P**roperty **R**ight
IPTO	**I**nformation **P**rocessing **T**echniques **O**ffice
ISR	**I**ntersecting **S**torage **R**ings
ISTO	**I**nformation **S**cience and **T**echnology **O**ffice
ITLO	**I**ndustrial **T**echnology **L**iaison **O**ffice
LEP	**L**arge **E**lectron **P**ositron collider
LHC	**L**arge **H**adron **C**ollider
MS	**M**ember **S**tate
PDAS	**P**ai**d** **As**sociate

PDSA	**P**ai**d** **S**cientific **A**ssociate
PET	**P**ositron **E**mission **T**omography
PJAS	**P**ro**j**ect **As**sociate
P-S	**P**acket **S**witching
PS	**P**roton **S**ynchrotron
R&D	**R**esearch **&** **D**evelopment
SC	**S**ynchro-**C**yclotron
SISO	**S**oftware **I**ntelligent **S**ystems **O**ffice
SoP	**So**cial **P**rocess
SP	**S**cientific **P**rocess
SPC	**S**cientific **P**olicy **C**ommittee
SPL	**S**upplies, **P**rocurement and **L**ogistics
SPS	**S**uper **P**roton **S**ynchrotron
STAF	**Staf**f Member
SUMM	**Summ**er Student
SURV	**Surv**ey Trainee
TAB	**T**echnology **A**dvisory **B**oard
TECH	**Tech**nical Student
TP	**T**echnological **P**rocess
TT	**T**echnology **T**ransfer
UCLA	**U**niversity of **C**alifornia, **L**os **A**ngeles
UCSB	**U**niversity of **C**alifornia, **S**anta **B**arbara
UNESCO	**U**nited **N**ations **E**ducational, **S**cientific and **C**ultural **O**rganization
UPAS	**U**n**p**aid **As**sociate
UPSA	**U**n**p**aid **S**cientific **A**ssociate
USER	Temporary **User** coming from other laboratories
USSA	**U**npaid A**ss**ociate with daily **A**llowance
WWW	**W**orld **W**ide **W**eb

Contents

1. Introduction

The general aim of this research is to examine the acquisition of knowledge in an inter-governmentally funded scientific research organization, the European Organization for Nuclear Research (CERN), in Geneva, Switzerland. In particular, it aims to answer two main questions. The first question addresses the educational impact of CERN on students and apprentices. A related aspect is the competitive core skills and acquired knowledge developed and the market value of these skills for Member States' (MS's) industries. The second question asks how people's exposure to an international environment enhances cultural and social dimensions and how society benefits from this exposure. This analysis of technology transfer through people is based on a new model, representing the CERN knowledge creation path, from the individual's learning process to knowledge acquisition in an organizational context and the knowledge transferred from CERN to other institutions.

CERN's origins can be traced back to the late 1940s, when a small number of visionary scientists in Europe and North America identified the need for Europe to have a world-class physics research facility. Their vision was both to stop the brain drain to the United States of America that had begun during the Second War, and to unify post-war Europe. In 1951 a provisional body was created, the Conseil européen pour la recherche nucléaire (CERN). In 1953 the Council decided to build a central laboratory near Geneva.

CERN was created on 29 September 1954, when the Convention for its establishment was ratified by the parliaments of the twelve founding Member States: Belgium, Denmark, France, the Federal Republic of Germany, Greece, Italy, Norway, the Netherlands, United Kingdom, Sweden, Switzerland and Yugoslavia. Yugoslavia left CERN in 1961. Austria and Spain joined in 1959 and 1961 respectively. Spain left the Organization in 1969 but rejoined in 1983. Portugal joined in 1985, Finland and Poland in 1991, Hungary in 1992, the Czech and Slovak Republics in 1993 and Bulgaria in 1999, bringing the number of Member States up to its present total of twenty.

CERN's goals are clearly set out in Article II of the Convention: *"The Organization shall provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto. The Organisation shall have no concern with work for military requirements and the results of its experimental and theoretical work shall be published or otherwise made generally available."* This established from the very beginning the innovative concept of open international scientific co-operation that has been the foundation of the Organization's success over the last 50 years. *"Scientific research lives and flourishes in an atmosphere of freedom – freedom to doubt, freedom to inquire and freedom to discover. These are the conditions under which this new laboratory has been established."* These were the words written in 1954 by Sir Ben Lockspeiser, first President of the CERN Council.

According to the Convention, the laboratory is officially the Organisation européenne pour la recherche nucléaire or European Organization for Nuclear Research. However, the name of the Council stuck to the organization, generally referred to as 'CERN'. (It is a common mistake to think that the 'C' stands for 'Centre' instead of 'Council'.) At the time of CERN's foundation, pure physics research was focused on understanding the inside of the atom, hence the word 'nuclear' in the official name. Very soon, however, work at the laboratory went beyond the study of the atomic nucleus, into higher and higher energies. Therefore CERN was regarded as a high energy physics institute from very early on. CERN's history is bound up with the construction of large accelerators. The Synchro-Cyclotron (SC, 1957) and the Proton Synchrotron (PS, 1959) were followed by the Intersecting Storage Rings (ISR, 1971) and the Super Proton Synchrotron (SPS, 1976). CERN's largest accelerator so far, the Large Electron-Positron storage ring (LEP) began operating in 1989, but has now been dismantled to make way for the Large Hadron Collider (LHC). As its activity is mainly concerned with the study of interactions between particles, CERN is also commonly referred to as the European Laboratory for Particle Physics (Laboratoire européen pour la physique des particules), which, in fact, best describes the current work of the Laboratory. To summarize, for the public CERN is the European Laboratory for Particle Physics, and formally it is the European Organization for Nuclear Research. CERN undertakes pure scientific research into the laws of nature and is not involved with nuclear weapons.

CERN is now the world's largest high energy physics research laboratory. At present, India, Israel, Japan, the Russian Federation, Turkey, the United States of America, the European Commission and UNESCO all have observer status. There are now more US scientists working at CERN than there are Europeans in US particle physics laboratories. About 2360 staff members, and 400 students and fellows are supported by the Organization, and 6500 visiting physicists, engineers, computer experts and scientists, from 80 countries and 500 scientific institutions specializing in a variety of front-line technologies, collaborate with CERN.

Binding together the creativity of individuals from so many different national backgrounds and fields of research has established CERN as the global centre for high energy physics and has set a precedent in scientific collaboration, which has been followed by Europe’s other fundamental research organizations. CERN is currently engaged in its most ambitious programme yet and is building the most complex scientific instrument of its history: the world’s most extensive interconnected system of accelerators and storage rings – the Large Hadron Collider (LHC). This new research facility – a circular particle accelerator 27 kilometres in circumference - will collide protons and other nuclei head on, creating conditions that have not existed since the earliest stages of the Universe. With the detectors that will capture quarks and gluons colliding in the TeV energy range, the LHC will probe questions including what is the mysterious dark matter of the Universe made of? Why do particles have mass? And what was the Universe like in the first fraction of a second of its life, before matter started to cool into the form it has today? As CERN’s first accelerators were catalysts for European collaboration, the LHC will start in 2007 and set a precedent for worldwide collaboration in physics research.

CERN has been a centre of knowledge creation since its inception. Statistical data show that each year the laboratory welcomes many students, researchers, and visiting scientists, that many publications are produced, and that some of these visitors then take their acquired experience and knowledge to industry. These statistics testify that CERN is successfully fulfilling its original goals. Nevertheless, no systematic studies on the kind of knowledge produced, how this knowledge has been acquired, and how individuals have and, consequently, society has benefited have never been undertaken. This was the fundamental motivation for starting this research.

The investigation carried out in the preliminary phase of the thesis was devoted to understanding the different pathways through which knowledge and know-how is acquired at CERN. The transfer of know-how by technology transfer (TT) through people[1] following employment at CERN was investigated in a sample of several hundred Finns and Italians who participated in CERN scientific programmes on a variety of contracts during the LEP period (1990–1999). A questionnaire was developed, tested and made available to the selected study sample in order to collect information on the competitive core skills and knowledge acquired during the work experience at CERN. While Finland and Italy represent the sampling population of this study, it would be valuable to expand the study to other Member States.

In order to represent the knowledge creation process in CERN, a research organization where specific scientific knowledge is acquired, it is necessary to develop an underlying model on which to base the analysis of this research. This model was constructed on the basis of two knowledge creation models. First, Kaarle Kurki Suonio's model of knowledge creation in the learning process, and second, Ikujiro Nonaka's[2] model of knowledge acquisition in an organizational context.

This thesis contains in total 9 chapters including the introduction, Chapter 1. Chapter 2 outlines and limits itself to describing the main features and principles of technology transfer at CERN. Chapter 3 describes the knowledge creation path: from individual learning to organizational acquisition. A part of this chapter refers to the relation between knowledge acquisition, social capital, and competitive advantage for CERN and its users and is based on a study on entrepreneurial high-technology ventures based in the UK. The core of this chapter introduces the knowledge creation theories and is dedicated to the construction of the new model of knowledge creation,

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[1] This expression indicates the transfer of technological knowledge made by people between different places of work.

[2] Kaarle Kurki Suonio is Professor Emeritus at the Department of Physical Sciences, Helsinki University, Finland. Ikujiro Nonaka is Director of the Institute of Business Research, Tokyo Hitotsubashi University, and Professor at the Centre for Research and Investigation of Advanced Science and Technology in Tokyo, Japan.

acquisition and transfer in CERN. Chapter 4 is devoted to the research objectives and methodology of the study. The questionnaire design is described in the same chapter. The statistical considerations on samples and responses are treated in Chapter 5. Chapter 6 discusses the research questions, the data, and the analysis results. Chapter 7 is devoted to the summary of knowledge, social impact and communication. Chapter 8 gives the conclusions and a discussion of possible future developments. References are indicated in Chapter 9.

Finally, the present work will hopefully help to define a strategy aimed at improving technology transfer through people, which could be generally applied to any sample independent of the nationality within the CERN Member States.

For editing reasons all the acronyms present in this text are specified in the list at the beginning of this manuscript.

2. Technology transfer at CERN[1]

Technology transfer through people is an essential part of the technology transfer process. After having summarized the CERN origin and mission in the introduction, this chapter outlines the historical development and the actual mission and strategy of technology transfer at CERN in order to contextualize the environment where the research has been carried out.

2.1 The birth of technology transfer culture and formalization of the process

Particle physics as carried out at CERN and similar laboratories is basically an experimental science. For conducting their research, physicists require large and complex tools such as accelerators and detectors exploited by powerful data analysis systems. Progress in the discipline is directly related to the performance of its experimental facilities that are in turn determined by the state of the art of the underlying technologies [Bar97]. As in other high technology sectors such as space launch and satellites or nuclear power plants, financial limitations are a major factor in the design of particle physics facilities. The challenge is not to reach the design goals whatever the price, but to do the best possible physics within the allocated budgets.[2]

In spite of the obstacles, since its creation in 1954 CERN has had a long tradition of partnership with industry making its technologies available to third parties. Particle physicists have pioneered their applications for research. CERN does not anymore host the largest European computer centre as was the case in the 1960's and 1970's. In addition to the computer centre, which is essential for all aspects of scientific work, high-performance machines are used in the experiments to organise the signal data acquisition and data store, to reconstruct physics events and to extract novel information from a mass of data. Computer systems are also used for process control of all accelerator and detector systems as well as for the management of the site technical infrastructure.

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[1] The information reported on this Chapter refers the situation as such till the end of 2003. The TT group has now moved in the Organization's internal structure to the Director-General's office.

[2] The etymological origin of the word 'technology' corresponds to techno + logos, which means knowledge about techniques; in a pragmatic definition the word 'technolo*gy'* represents a 'set of high-tech products'.

The fact that CERN members come from remote locations and would like to perform as much data analysis as possible in their home institutions has lead to the development of data networks between CERN and these institutes with a rapidly increasing capacity to accommodate the fast-growing traffic. The result is that CERN has become one of the major hubs of the European scientific data network and it is in a way retrospectively natural that it was the birthplace of the World Wide Web (Appendix A).

Beside the computer systems, the technology domains developed at CERN during the fifty years of its life can be summarized as: computer technology, electromechanical engineering, mechanical engineering, material science, radio frequency and microwave engineering, superconductivity, cryogenic technology, ultra-high vacuum and electronics. Figures 2.1, 2.2 and Table 2.1 refer to all the technology development collaborations, by country and by technical domain respectively, from 1985 to 1995. These figures are a measure of CERN's first efforts and actions to stimulate the process of technology transfer (TT). They do not constitute as such a proper monitoring of the achieved transfers or of any specific result. These examples of technologies in the field of detectors and accelerators are strategic not only for the Laboratory but are also of interest to a number of other accelerator laboratories worldwide. Technologies developed at CERN often correspond to niche markets and foster close relationships with industry in a wide range of technical fields, in order to have available the best possible instruments at an affordable cost.

Table 2.1: Number of CERN technology development collaborations [Bar97].

	1985-88	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**
Number of new projects	81	25	35	34	23	23	13	23
Cumulative number of projects	81	106	141	175	198	221	234	257
Cumulative number of collaboration partners	77	87	136	185	220	250	271	320

The most challenging task for the TT group is the timely detection of promising innovation. This is very difficult in an academic environment because of the lack of market culture and perception. Active TT actions in the CERN environment often face a number of obstacles due to the very deep cultural differences between an institution committed to basic scientific research, with free exchange of people and ideas, and industrial firms with a profit-oriented perspective.

A basic element of the culture of the academic world of which CERN is an integral part is the publication of research results in open scientific literature. It is on the basis of these publications that results can be analysed, evaluated, and reviewed by other scientists.

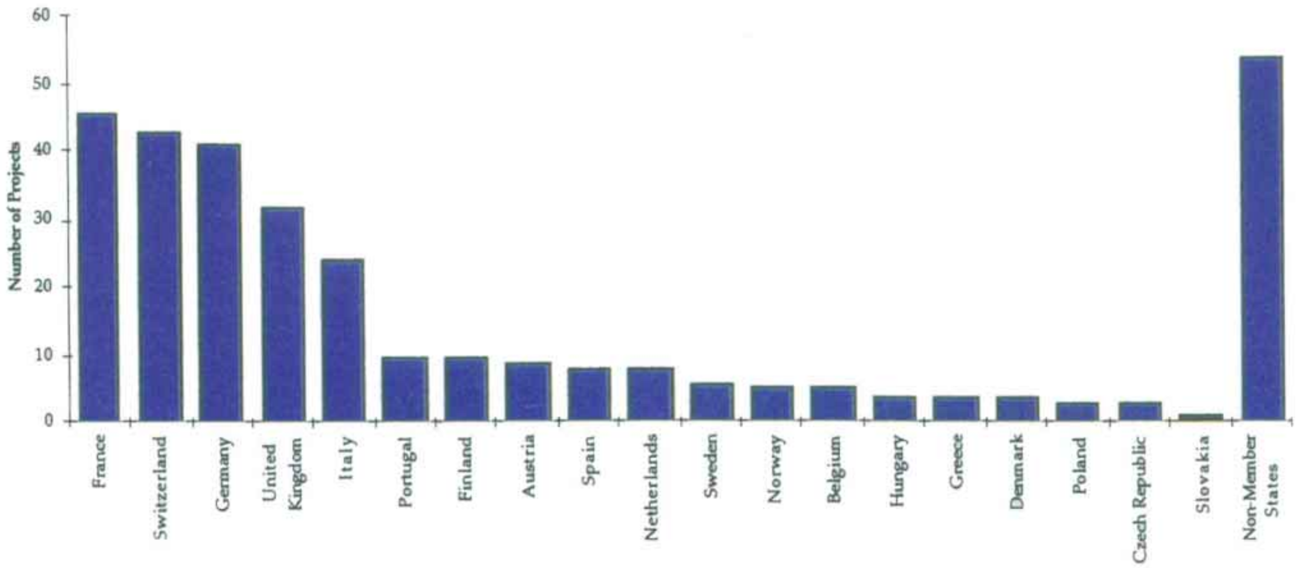

Fig. 2.1: Cumulative distribution of technology collaborations by country [Bar97].

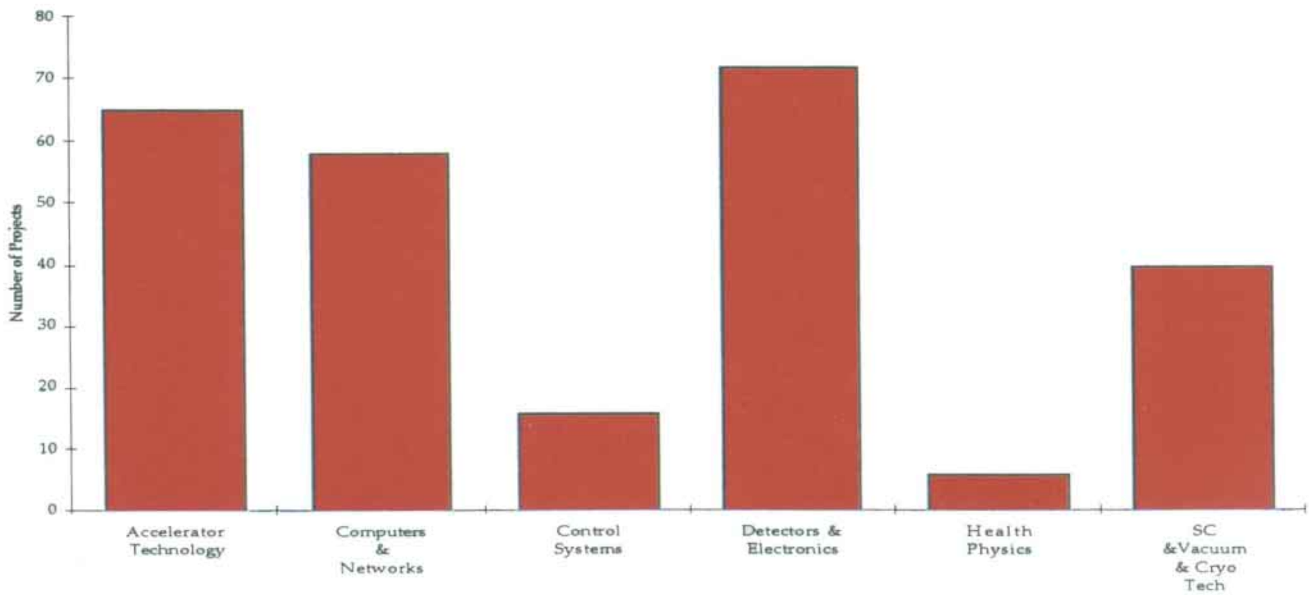

Fig. 2.2: Cumulative distribution of technology collaborations by domain [Bar97].

Furthermore, the very process of science is based on the free exchange of ideas and communication of results. CERN's founding Convention, which requires that the Organization publishes and makes generally available the results of its theoretical and experimental work, was written in full agreement with this universal practice. CERN applied physicists and engineers may publish their results in CERN reports or scientific and technical journals, but a more frequently used medium is the presentation of technical progress at regular specialized international technology transfer conferences. These major technology conferences and exhibitions, which CERN has often organized, have been important occasions to establish relationships between CERN and industry. The first took place in 1974 [Jes74], another was in 1979 to celebrate the 25th anniversary of the Organization; this was also the establishment of the location for the permanent Microcosm exhibit. Another exhibition was organized for the LEP inauguration.

The difficulties of an active patent policy existed already in the 1980s [RCR87]. Except for the protection of computer software through a copyright statement that has been systematic since the mid 1980s for the computer centre programme library and later to all software developed by the divisions, there was no structure in the Laboratory, or dedicated resources, to support an innovation policy. Indeed, during the first thirty years of its life, CERN did not use intellectual property (IP) protection mechanisms such as patents, as this was seen as being in contradiction with the articles of the CERN Convention. The policy was 'publish or perish', rather than 'patent and flourish'. It was also considered that the required confidentiality and the supposed difficulty in establishing the list of inventors would have negative consequences on the open and free relations between CERN and its users [Bou99].

Furthermore, for tendering contracts CERN financial rules required competitive bidding with award to the lowest offer, and were not adapted to collaborative agreements with the technically most knowledgeable or motivated partner.[3] The situation was made worst by the procurement rules, which only aimed at achieving a balanced financial return to Member States independent of the

[3] The method developed more than 25 years ago by CERN to evaluate the economic utility resulting from contracts [Sch75, Str84] was confirmed in a study sponsored by the Helsinki University of Technology on industrial suppliers' strategy in relation to CERN contracts [Nor94].

technological content of contracts and not in line with practice in the other European scientific institutions.[4]

To summarize, CERN financial rules, which governed transactions involving expenditure from the Organization's budget, were based on three principles: competitive bidding, acceptance of the lowest priced technically satisfying offer, and the objective of well-balanced financial return for all MS. The other essential component of CERN is its international character. Whilst it is a natural and accepted rule in national research laboratories to establish and develop privileged relations with their national industry, CERN must offer opportunities and give access to its technology to firms from all MS.

In 1984, when beginning to plan the LHC machine, it was recognized that in view of the magnitude and technical complexity of the project, a strong involvement of industry, already at the initial R&D stage, would be essential. This was also seen as an effective way of technology stimulation and transfer. In 1986 an internal committee analysed in depth the relations between CERN and industry and the Finance Committee (FC)[5] accepted the development concept in 1988. In this year, CERN was told by its MS to take a more pro-active attitude towards TT and there was

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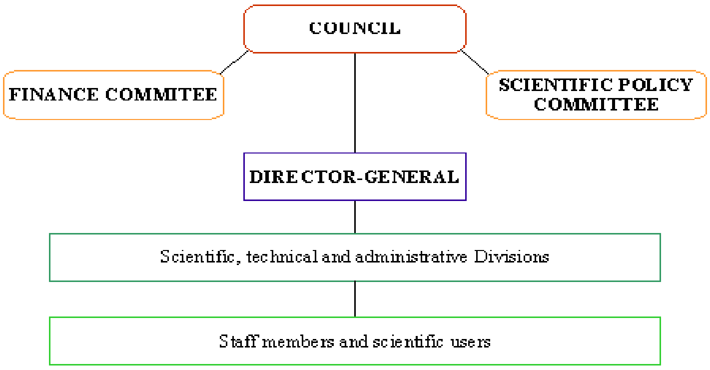
[4] The Member States provide financial contributions in proportion to their Net National Incomes. CERN's budget is drawn up in Swiss francs and the budget currently amounts to almost one thousand million francs, comparable to that of a medium-size European university. Each MS has two official delegates.

[5] Finance Committee (FC) and SPC (Scientific Policy Committee) are special committees subordinated to CERN Council. The structure of CERN is designed to allow flexible operation and to ensure that it remains responsive to the needs of the scientific community it serves. The Organization chart (see figure below) shows that the original alliance of scientists and politicians which led to CERN's creation left its indelible mark on CERN in the form of the two-member representation of each MS in Council.



The Council bears the ultimate responsibility for all important decisions affecting the Organization and its activities (carried out in the divisions grouped in research, accelerator, technical and administration sectors by a highly qualified personnel) and the separate responsibilities of two subordinate committees: the SPC, which examines the particle physics options and makes recommendations regarding CERN's scientific program of activities, and the FC, which is composed of representatives from national administrations and deals with all issues relating to financial contributions by the MS and to the Organization's budget and expenditure. The Director-General (DG), appointed by Council usually for five years, is the head of the CERN management and is empowered to act in its name. The DG, who runs the Laboratory through a structure of divisions, is by tradition a scientist and is assisted by a Directorate, comprising half a dozen members whose appointments he proposes to Council to which he alone is directly answerable. He can propose to Council any adjustment he deems necessary to meet the evolving needs of the research program.

the formal establishment of the Industrial Technology Liaison Office (ITLO)[6], which can be considered the beginning of TT policy at CERN. The Industrial Technology Liaison Office's mandate has been:

- To act as a unique point of contact for industry for all aspects not directly related to procurement.
- To strengthen contacts on industrial matters with CERN MS delegates and the Industrial Liaison Officer (ILO[7]), as well as external bodies including commercial attachés, chambers of commerce, regional bodies, industrial parks, etc.
- To promote and assist TT by all relevant means.
- To ensure that CERN's intellectual property rights are adequately protected and correctly exploited.

In the period 1988–1990 a few patents were filed to gain experience in order to be in a position to evaluate the interest of a systematic patent policy [Bar95]. The call for technology, launched in 1991 for the development of the LHC detectors, was another occasion to reinforce the relationships between CERN and industry. In order to facilitate the protection of possible TT negotiations, as well as protecting the Organization's interests, CERN rules were revised in 1995. All intellectual property rights (inventions, copyright material, designs, as well as technical and other developments) resulting from or substantially based on the personnel's activities at CERN are now registered by the Organization [CSR96].

CERN has been aware for a long time of the large technological interest arising from its activities. The Organisation never had resources for TT on a scale that was commensurate to the potential of the technologies resulting from its activities. In order to encourage an increase in exchange of technology between industry and CERN, in March 1997 a working group of the Finance Committee requested and recommended that the management develop an enhanced TT policy. The immediate priorities to achieve such a policy were identified in the course of 1998 and the TT policy was endorsed on 10 March 1999 [FCP99]. This policy defined the essential

[6] Industrial Technology Liaison Office is a part of CERN's structure, that helps the staff at public research to identify and manage the Organization's intellectual assets, including protecting intellectual property and transferring or licensing rights to other parties to enhance prospects for further development.

prerequisites needed to make known and available to third parties in the MS technologies having market value, whether technical, social or financial.

In June of the same year, Council established a structure to assist the Director in charge of TT to perform his task and consequently to create a new division: the ETT division (Education and Technology Transfer division), one of its essential aims being to enhance TT activities at CERN. Finally, in January 2000, ETT division (Fig. 2.3) came into existence. At the beginning TT activities have been divided into two closely collaborating groups: Technology Transfer (TT) and Intellectual Property Rights (IPR). The combination of both corresponded to the existing Industrial Technology Liaison Office and covered complementary aspects of the same policy, which aimed to make known and available to third parties, under agreed conditions, technical developments achieved in fulfilling the laboratory's mission of fundamental research. Starting from that moment and CERN-wide, the Industrial Technology Liaison Office catalysed, promoted and guided all aspects of the TT service [FCP00]. From 2001 the TT and IPR groups have been unified into one TT group.

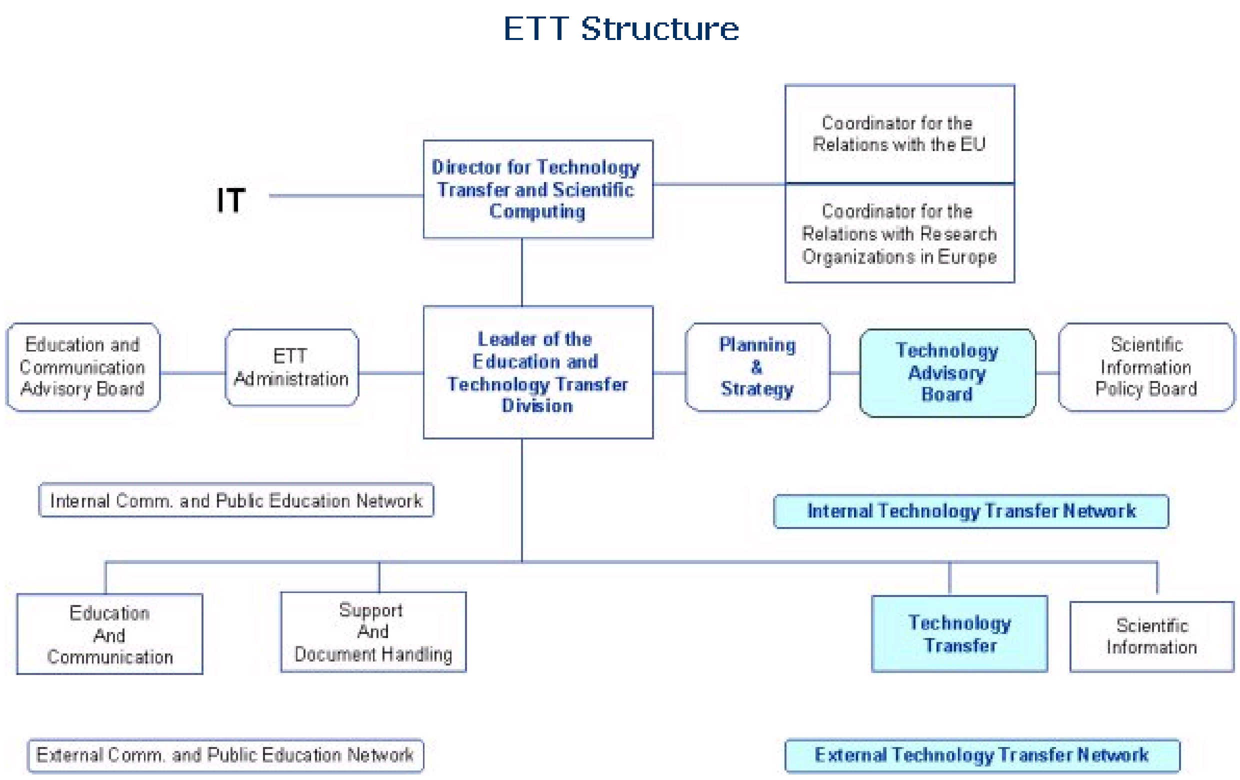


Fig. 2.3: Structure of the CERN ETT division [Gou02].

[7] Industrial Liaison Officer is a part of CERN's structure, which helps the staff at public research to identify and manage the Organization's intellectual assets.

2.2 Technology transfer: a summary of mandate, structure, strategy, and policy

The transfer of technology is a way to improve scientific dissemination, to wake up the general public to the benefits of science, to fund more fundamental research and to motivate scientists for more challenging scientific projects.

As defined, technology transfer is a goal-oriented interaction between two or more social entities, during which the pool of technological knowledge (and skills) remains stable or increases through the transfer of one or more components of technology [Aut95].

CERN's prime TT asset is the availability of the large spectrum of technologies geographically located within walking distance of each other. It is important to note that a large fraction of CERN technologies (60%) are documented through internal notes. In addition to the tasks concerned with TT, the ETT division has been mandated to be responsible for activities related to public education, such as the press and visit services, the library, and the document handling services, aiming:

- To demonstrate the relevance to society of particle physics research beyond its contribution in terms of pure research.
- To communicate technical innovation to industry and to other science.
- To promote the image of fundamental research performed at CERN and in its collaborating institutes in Europe as generators of technology.

The mandate of the ETT division can be summarized as follows: to demonstrate and communicate to social groups and society at large, in co-operation with the collaborating institutes, the scientific results achieved by the CERN programme, their cultural and educational implications as well as the technologies and methods developed in the accomplishment of CERN's basic mission [FCP99; FCP00; FCP01; FCP02].

2.2.1 TT structure and mandate

The MS assist the Industrial Technology Liaison Office in TT-oriented activities in their respective countries. A special organism, the Technology Advisory Board (TAB), reviewed the general policy and all the TT activities for improving the strategy. The chairman of the TAB was CERN's director responsible for TT. The composition of its members was appointed by the Director-General and included senior specialists from the major technical domains at CERN as well as representatives from the Purchase and Legal Service[8]. By pursuing fundamental research CERN attracts talented young people to science, developing novel technologies, pushing existing technologies beyond customary limits, developing novel combinations of technologies and providing constant training opportunities in technologies and their technical developments. The CERN TT service is mandated to identify, promote, protect and transfer technologies developed at CERN in research, accelerator and information technology domains to industry.

2.2.2 TT strategy and policy

The strategy adopted for achieving transfer through a pro-active intellectual property rights (IPR) policy is through personnel, purchasing, collaboration agreements and special projects. During the process of transferring technologies to industry (Fig. 2.4), the various steps involve either know-how or patented and non-patented technologies. An important aspect of TT policy, which became a high priority, was the development of a TT culture within CERN and the general acceptance of TT as an essential part of the Organization's mission. First, it was important to underline that a pro-active policy was not in conflict with the publication of the laboratory's scientific results since, in particular, scientific discoveries, theories and mathematical methods are excluded from the scope of all present patent laws. In this framework, CERN enhanced its policy of encouraging contacts with industry, and of providing appropriate incentives, advice and information on the protection and transfer of its technology to society at large, to the benefit of the MS. It clearly

[8] In particular: director in charge of TT, head of the ITLO, ETT division leader, leaders of TT services, coordinator for the relations with EU, coordinator for the relations with research organizations in Europe, a member of the legal service, a member of Supplies, Procurement and Logistic (SPL) division, senior experts from the Laboratory in its main high-tech areas, senior external experts in domains for which CERN technologies could be applied, as well as from technology parks, industries and IPR experts.

identifies CERN's subsidiary role as a generator of technology that, in general, is often overlooked by the public at large.

The Organization wants to identify any know-how previously invested in a technology emerging from CERN and to patent its inventions outside Europe in order to protect its MS industries from foreign competition. In this sense, once a patent is filed it is important that the CERN TT service and the respective inventors invest effort in licensing the invention in a timely manner. The main aim of the TT policy is to raise awareness of CERN or particle physics technologies, both inside and outside CERN, to include intellectual property right statements systematically in collaborative development agreements, and to keep patents normally for a limited period only unless subsequently licensed to potential users. Patenting policy has been followed to optimize the transfer of technologies and to keep cost under control.

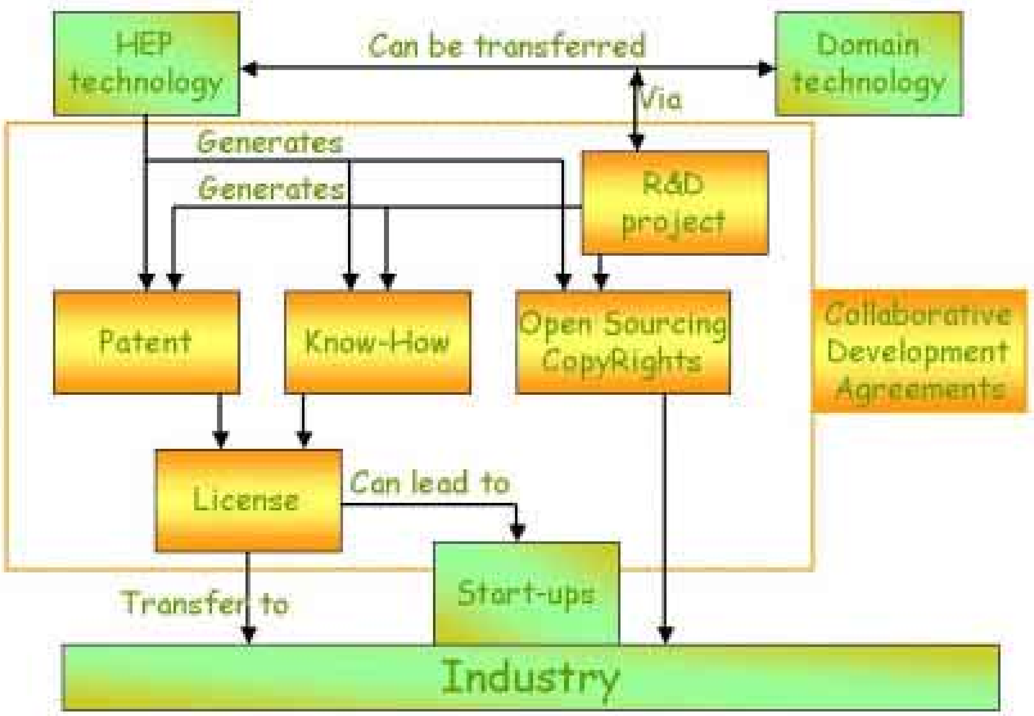


Fig. 2.4: CERN TT process [FCP02].

It is important to file patents when they are deemed promising from the marketing point of view, and to extend them only when a market opportunity really appears. In order to carry out this transfer to industry efficiently, agreements should be established at an early stage to facilitate intellectual property ownership and know-how before licensing the technologies. Through a policy of encouraging protected agreements with outside bodies (institutes, companies, etc.), CERN can not only increase its visibility but also complement its financial resources in order to finance other TT activities. CERN is following a strategy of responsive intellectual property rights, which is summarized in Fig. 2.5.

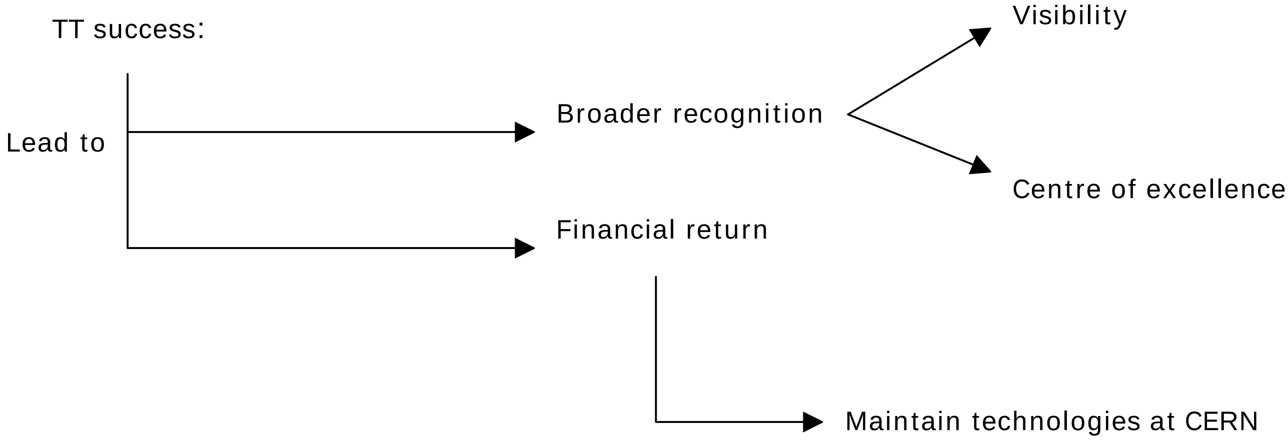


Fig. 2.5: CERN IPR strategy [FCP01].

Up to now the pro-active TT experience has lead to very considerable progress in realizing the importance of the CERN technology potentiality and identifying the mechanisms by which European industry can benefit from CERN technologies and TT activities. Thanks to the TT activities, the Organization can draw on resources from outside which are becoming more and more necessary to support the TT process. In this way TT is drastically decreasing its dependence on the CERN budget. In addition CERN, together with its collaborating institutes, is making more use of European funds for endeavours derived from particle physics technologies. The results achieved up to now show that TT assures not only a constant exploitation of CERN technologies, but also an increasing flow of revenue. The scope of opportunities is very large and TT can be further enhanced if the additional external resources are obtained.

2.3 Outlines of main technology transfer activities

The number of CERN technologies is very large and growing steadily. The LHC is a high-technology project of extreme complexity. Just overcoming scientific and technological challenges without precedent and examining the applications of its technologies in the medium and long term, LHC will have a considerable technological impact on society and can be considered a real ‘gold mine’ of technologies to discover. Patents as well as licences, collaborative development agreements and consultancy agreements are important means to protect technology and know-how and transfer it to industry. These mechanisms, as well as TT-related R&D special projects, TT through people and purchasing, and promotional activities such as TT events make CERN widely known in fields other than HEP and help to foster public recognition.

2.3.1 TT through patents, licences, and agreements

Up to now industry has shown real interest in CERN technologies as many signed agreements of collaboration with industry and other institutions testify. CERN shall only enter into a working relationship with partners who have a good chance of success and have a good reputation. While the joint projects concerned are usually carried out to the mutual satisfaction of both parties the considerable TT that takes place has rarely been the subject of formal study or reporting back to the Finance Committee in the context of TT. At present the CERN portfolio consists of 22-patented technologies. The evolution of the patent portfolio cost over the past 6 years is shown in Table 2.2. Starting with a cost of 6 kSFR in the year 1995, the maintenance of the patent portfolio reached 260 kSFR at the end of year 2000 and 352 kSFR in 2003. In general, the careful handling of the patenting process has allowed the patent costs to remain almost unchanged from the previous year. In fact, while the number of patents was increasing, the costs have been partially recovered through the licensing of patented technologies.

Table 2.2: Evolution of the cost of the patent portfolio during 1995–2003 [FCP03].

	1995	1996	1997	1998	1999	2000	2001	2002	2003
Portfolio cost (kSFR)	6	15	88	70	220	260	260	310	352
Nº of technologies for which patents have been filed	1	2	5	6	10	12	16	19	22

Note: SFR = Swiss Francs

There are three main types of agreements that involve intellectual property rights issues: licences of technology or know-how, collaboration development agreements, and consultancy agreements. Both licences and consultancy agreements are particular forms of collaboration development agreements, which concern the exploitation of CERN know-how. Licensing takes place whenever non-exclusive transfer of the particular technology may reduce the expected benefits. The Director-General may grant exclusive rights to the partner, after consultation with the Technology Advisory Board. Consultancy agreements are used when CERN is asked from outside to provide specialized advice and to transfer the know-how and unique experience of some of its staff. In such collaboration development agreements, clearly both the companies and CERN derive benefits.

Agreements related to developments in accelerator, magnets, cryogenics, vacuum, radio frequency, mechanics and material sciences correspond to about half of the cases, demonstrating the impact of the LHC machine design and construction on the number of agreements. The distribution of the 160 current agreements in the different domains of activity at CERN is reported in Table 2.3 and the distribution by institutes and industries covered by the agreements is shown in Fig. 2.6. The large number of agreements with Russia is due to manufacturing, assembly and testing of large detector components of the LHC.

Table 2.3: Agreement distribution by technology domains at CERN [FCP02].

Accelerators	Magnets	Cryogenics	Vacuum	Radio frequency	Others
7%	9%	9%	6%	4%	21%
Mechanics	**Material sciences**	**Electronics**	**Detectors**	**Information technology**	
8%	7%	4%	4%	21%	

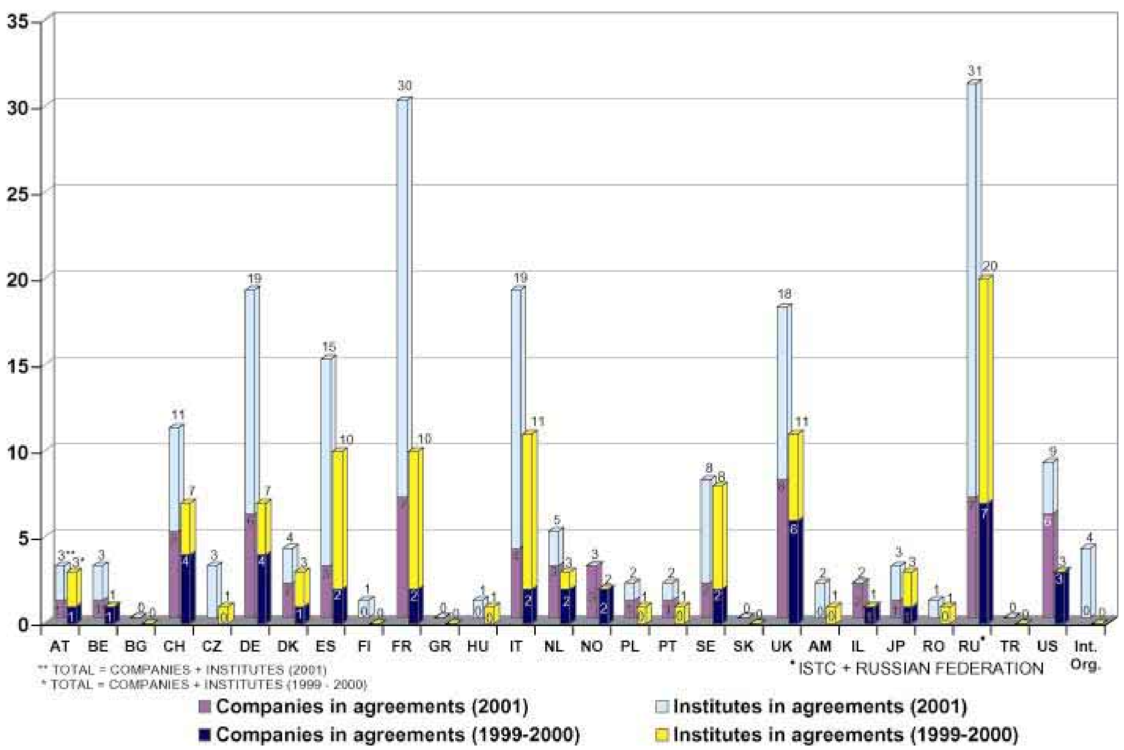


Fig. 2.6: Agreements distribution by country companies and institutes at CERN [FCP02].

2.3.2 TT through R&D projects

There are areas where particle physics technology could be of great relevance to other fields and disciplines, such as biomedicine, information technologies, materials, energy and the environment. Activities in the biomedical area are a particular example where the use of developments in particle detectors could be applied in medical diagnostics and the use of accelerator know-how to provide hadron therapy, beneficial in the treatment of tumours. The medical and biological domains also benefit from HEP software, in areas such as testing and validation of simulation software and in user requirements stimulating new models and developments [Cha01]. Therefore, one of the obvious areas of primary TT interest is the biomedical application of CERN technologies, not only such as accelerators for radiation therapy but also for production of medical isotopes, sensors, effects of ionising radiation, imaging and simulation. In all R&D projects resulting from the TT process the expected role of CERN is to provide the existing know-how, together with the collaborating institutes, and minor support. In some projects CERN is expected to co-ordinate the activities. These projects are reviewed by the Technology Advisory Board to make priorities for funding and assessing the availability of resources at CERN that can be used for developing the selected projects. In any case external institutes and companies provide most of the funding, and in 15 cases funding came from the European Union.

2.3.3 TT through people

A most important part of the transfer of technology from CERN comes clearly through the transfer of knowledge or know-how of people. Within CERN and the institutes collaborating in the CERN physics programme there are experts in many technology fields needed to perform the core business of fundamental research. This expertise is being transferred continuously through people to outside industry and institutions in several ways. Some industrial firms have also asked CERN to host, at their own expense, engineers or applied physicists for training periods of several months by working on CERN projects. All these people have access to the rich programme of seminars and training courses held at CERN, covering a wide range of state-of-the-art topics. They are cornerstones in the high level training of scientists from all over in research and technology. A study showed that some 40% of the researchers who participated in DELPHI, one of the LEP experiments, are now working in industry [Cam96].

Each year hundreds of young people join CERN as students, fellows, associates or staff members on first employment. After the completion of their thesis, fellowship, or contract, the value CERN adds by working in an exchange of knowledge enables them to find their next job in their home country. Many will not stay in research or even continue to work in physics, but at the end of their stay at CERN they will have acquired many of the qualifications expected by industry: experience of teamwork, working to tight deadlines and budgets, international co-operation, experience of data processing and acquaintance with a variety of advanced technologies. CERN offers students training possibilities in a wide area of research and high-tech activities in all the scientific and technical fields in which the laboratory is active as part of their curriculum and, in return, CERN benefits from their dynamism, ideas and willingness to learn and integrate in the research or technological world.

In summary, the continuous flow of people who come to CERN, who are trained by working with CERN's experts and who then return to their MS is a particularly useful example of TT through people.[9] Experience shows that industry, universities, and other private and public employers value these people and the on-the-job training they receive at CERN highly. For this reason CERN has a longstanding, successful record of stimulating and exploiting TT through people. Currently there are programmes with Member States providing young people with technological training at CERN, so young professionals in CERN groups gain recognition for their stay as part of the CERN Education and Training programme. These programmes are supplemented with several TT-oriented courses on Intellectual Property Rights and aspects of TT, as well as certain aspects of entrepreneurship and policy.

[9] The notion of 'expert' is relative and when used as a qualifier often a measure of some lack of competence in the third party. If one person is more knowledgeable than the other, the former is in a position to transfer his or her know-how to the latter as consultancy, and such actions deserve a return, whether financial or in kind. Therefore, identifying experts in an organization requires the identification of the credentials of personnel through as many independent sources of information as possible.

2.3.4 TT through shared learning

Technology training is an integral part of the experimental research process. Young scientists contribute to the design and construction of experiments and thus become acquainted with leading physics instrumentation technologies. Other TT activities increasing the exchange of knowledge are the CERN Summer School of Computing, the annual CERN Accelerator School and the European School for Medical Physics, organized at both technical and scientific levels. CERN also offers technological training through its Accelerators and Computing schools, which are attended not only by researchers but also by engineers and applied physicists from industry. These schools bring together young researchers from various scientific disciplines and are combined with industrial exhibitions and seminars. The seminars are given by representatives of industry and present a direct platform for sharing technology and know-how between industry and research. The schools' strong focus on practical applications therefore allows the transfer of techniques and know-how developed at CERN to the Member States. But TT also occurs in the other direction, by fostering contacts and technical collaboration between local and national industry and research.

Table 2.4 shows the number of CERN fellows in applied physics and engineering (including computing), the number of unpaid associates in the same disciplines, and the number of apprentices and students between 1993 and 2003.[10]

Table 2.4: Number of CERN fellows and unpaid associates in applied physics and engineering (including computing), number of apprentices and students at CERN [CHR02].

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Fellows	140	111	127	153	200	219	215	203	225	215	221
Unpaid associates	598	679	573	596	180	155	175	203	229	322	310
Apprentices	26	28	29	30	30	30	31	31	31	33	34
Students	142	160	170	182	202	204	215	221	208	158	138

2.3.5 TT through purchasing

Since the creation of CERN the classical way by which technologies have been transferred to industry is through purchasing. This transfer of know-how occurs naturally from the interaction and continuous contact of CERN physicists, engineers and technicians with the suppliers of the equipment needed to carry out scientific research, i.e. research and development generating knowledge which spills over into fields other than HEP. The quantification of benefit and the analysis of CERN industry relations have been extensively studied [Häh97; Nor97; Sch75; Str84]. The basis for the analysis of secondary benefits to CERN suppliers, beyond the actual primary benefit through payments, has been established recently with the help of experts from Finland. This study evaluated the know-how acquisition by industry as well as the parameters that enable the industries and CERN to maximize the secondary benefits derived from suppliers with technological content [Aut03].

2.3.6 TT through promotional events

TT has supported some promotional events and exhibitions outside CERN and also facilitated a number of promotional events at CERN, including part of the LEP fest exhibition held at the occasion of the dismantling of LEP.

2.3.7 TT through start-ups and spin-offs

The high-intensity, high-energy accelerators and the related experiments are closely linked to novel technological developments, which are instrumental for achieving advanced capabilities at moderate costs. Many of these developments find an industrial application, essentially through two mechanisms. One is the implicit growth of know-how in basic technologies by industries that work in collaboration with CERN. This know-how is then applied in domains unrelated to HEP. A second mechanism, which requires a higher level of effort by industry and by the party that transfers the technology, relies on the extraction of a set of techniques that can be exported and applied coherently to a different domain. Instrumental to the success of CERN in HEP research is the fact that this kind of study requires a continuous improvement in the associated technologies. CERN has been a primary actor in these developments, since such technologies were not easily available on the market or in other laboratories. However, these kinds of developments require adequate industrial support in all the phases of the process. This mandatory connection between basic

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[10] For an overview of all types of CERN employment contracts see Section 5.1.2.

research, technology transfer and industrial involvement will be the basis of all the experimental physics activities in forthcoming decades, and will demand more and more investment in terms of material and human resources [Ama95].

CERN helps young entrepreneurs and in 2000 introduced a policy to support spin-offs[11] and start-up[12] creation. However, it is the intention to create incubators[13] on the CERN site for launching start-up companies. In order to avoid dilution of its know-how, CERN cannot promote start-ups without intellectual property protection. CERN will retain the intellectual property rights when technology is mission-critical and will instead seek for an exclusive or non-exclusive license.

Only in a few exceptional cases, CERN grants leave of absence for a limited period of time to staff who intend to create start-up companies from CERN technologies and the Industrial Technology Liaison Office establishes links with existing incubators in the MS. CERN offers easy access to its facilities, subject to conditions decided on a case-by-case basis by the Director-General, in conformity with the CERN Convention and financial rules.

2.4 Technology transfer promotion

In order to track and manage information on its technology assets, a database of information concerning all activities and an information network were created.

2.4.1 TT database

The TT database (see Appendix B) was developed as a dynamic data collection on technological solutions in the fields of CERN technologies to encourage rapid and efficient topical information gathering inside and outside the Laboratory.[14] The CERN TT database has two specific, immediate and interrelated aims, namely to provide a tool for the collection and subsequent monitoring of technology-related information at CERN, and to allow an initial audit of the potential value of CERN's

[11] Spin-offs are firms established by staff from a research organization to develop or commercialize an invention.

[12] Start-ups are new firms established specifically to develop or commercialize an invention licensed from a research organization, but without staff participation from that research organization.

[13] Incubators are technology structures meant to permit, assist and nurture young entrepreneurs for encouraging the formation and development of new and innovative technological ideas.

[14] The access to the TT database is http://www.cern.ch/ttdatabase, or, via web CERN Homepage, http://user.web.cern.ch/user/cern.html. In addition to its standard features the TT database allows data navigation, the advertising of events and video clips permitting on-line demonstration of selected technologies.

technology. The long-term objective is to provide a mechanism for two-way interaction with MS on issues of TT. The TT database, as an important contact for the flow of technology information developed and used at CERN, is also an effective working tool compiled and maintained by the TT Officers. It consists basically of a number of interrelated tables, including:

- Name and contact details of concerned people inside and outside CERN.
- Basic technologies involved in any development (product).
- Cases' history from a technical, financial and administrative point of view.
- Sources of technical information on MS.
- Patents, licences, collaboration development and consultancy agreements.
- Projects, benchmarking, market survey and standardization.

Up to now about 150 individual technology solutions have been identified and described in the TT database. The distribution by technological domain in the database is given in Table 2.5. To avoid specific user interfaces and to maximize platform-independence it was decided from the outset to provide all user access, public and private, by means of a Web interface. Thus all data is entered, modified and extracted using Web forms. For the reason of data security the navigation inside the database has been implemented and made available for obtaining TT information either for the public or for a private user, such as TT officer. Access to the public part by means of a Web interface is unrestricted, whereas the private contents are protected by a one-level password entry and are restricted to CERN's intranet. The intellectual property rights-sensitive data is included in the private content and for that a system of data encryption has been implemented to protect against the, albeit unlikely, unauthorized access to data in transit on CERN's intranet.

Table 2.5: Distribution of technologies listed in the CERN TT database [FCP02].

Accelerator	**Magnets**	**Cryogenics**	**Vacuum**	**Radio frequency**	**Others**
19%	5%	4%	4%	6%	7%
Mechanics	**Material sciences**	**Electronics**	**Particle detectors**	**Information technologies**	
3%	6%	15%	5%	26%	

Private access allows data search, submission, edit and delete, and operates on the whole of the TT database according to the privileges granted. Once past the login phase, a TT officer is able to search, submit, edit and delete products, contacts and technologies. In addition, the TT office is able to search in and submit tables of data on collaborating companies and institutes, patents held by CERN itself and CERN staff users (which includes links to relevant public patent database).

2.4.2 TT network

As awareness of TT continued to grow at CERN more formal communication channels were required between the divisions and the TT service, as well as within the divisions themselves and between CERN TT service and the MS. To respond to these needs there are two TT networks to assist and advise CERN TT activities. The Internal TT Network consists of members of other CERN scientific and technical divisions with special expertise in CERN technologies. These contacts are a valuable and necessary human interface between the central TT team and technology developers in the divisions. The role of the experts is to act as the focal point within the divisions on all matters relating to TT and to act as the first point of contact between a division and the TT service and vice versa. The corresponding External TT Network has been built up from contacts in institutes, industries and other experts in technologies of interest and TT from MS for mutual benefit. For getting more and more effective TT activities, experts in the Techno-Parks of collaborating institutes or in incubators are always very valuable and important in the creation of new spin-off companies.

2.5 The future for TT

The CERN TT unit intends to continue with its present two main lines of action:

- To identify and evaluate useful technologies and to facilitate their transfer.
- To support TT projects derived from HEP technologies and to promote specific transfers for useful applications outside of particle physics.

To facilitate this it is imperative that intellectual property and intellectual property rights issues be included in every collaborative development agreement, this being particularly important when industry is directly involved and especially when technology demonstrators need to be developed. Industry normally requires that intellectual property be protected in view of their subsequent possible market opportunities. The CERN patent portfolio will be regularly reviewed. The policy, which has been followed, is to file patents when they are deemed promising from the marketing point of view, and to extend them only when a market opportunity really appears. It is important to oppose patents from non-particle physics sources, claiming rights of particle physics technologies, to protect the HEP community and the interests of the MS, as and when necessary. CERN intends to make access to licences equally open to all its MS. Requests for licensing, however, normally come from specific sources in individual MS and there is a limited window of time to market. CERN will also continue to pursue a policy for start-up company creation [Rub02].

3. Knowledge, its creation, acquisition, and transfer in a research organization

The previous chapter discussed the environment in which the current research has been conducted, this chapter investigates the nature of knowledge creation from individual knowledge acquisition to that of organizational knowledge acquisition and is dedicated to the construction of a novel model of knowledge creation, acquisition, and transfer in CERN.

3.1 What is knowledge?

The analysis of this research, which examines knowledge acquisition in a research organization, is based on two different approaches. The first is the approach developed by Kaarle Kurki-Suonio to analyse knowledge creation in the learning process [Kur93] and the second is the approach of Ikujiro Nonaka that analyses the creation of knowledge in an organizational context [Non95]. This Chapter, covering the theoretical background to this study, includes material generated through personal interaction with Professor Kaarle Kurki-Suonio regarding his model of knowledge creation. In addition, the author borrows freely from Nonaka's work, where the model of knowledge creation in an organizational context is explained in great detail [Non95]. This Chapter contains the material from these sources necessary to introduce the author's own work.

To understand the differences between Kurki-Suonio and Nonaka's approaches, it is important to examine fundamental assumptions about what knowledge is and how knowledge emerges. The philosophical inquiry of knowledge is known as epistemology[1]. In other words, epistemology is the theory of knowledge. To understand this better, this section contrasts approaches to epistemology in the Western and Japanese intellectual traditions and provides a foundation for the study of this thesis which attempts to draw upon elements of both approaches.

As stated by Nonaka, in Western philosophy there has long been a tradition of separating the subject who knows from the object that is known [Non95]. This

[1] 'Epistemology' indicates the study of the criteria by which it is possible to qualify knowledge as science. Often confused with epistemology is the word 'ontology', which indicates the study of what exists and refers to the subject of existence.

tradition has its roots in Cartesian dualism [Non95]. The Cartesian dualism of subject and object or mind and body follows from the assumption that the essence of a human being lies in the rational thinking self. This thinking self seeks knowledge by isolating itself from the rest of the world and other human beings. Despite the fundamental differences between rationalism, which essentially says that knowledge can be obtained deductively by reasoning, and empiricism, which essentially says that knowledge can be attained inductively from sensory experiences, Western philosophers have generally agreed that knowledge is justified true belief.[2] Nevertheless, the definition of knowledge is far from perfect in terms of logic. According to this definition, our belief in the truth of something does not constitute our true knowledge of it, so long as there is a chance, however slight, that our belief is mistaken. Beliefs are identified with an individual's personal knowledge, which is the sum of the conclusions that an individual draws from experience and perception [Gre71]. Beliefs can also be called one's stable subjective knowledge. Concepts or conscious beliefs are justified and accepted by an individual and are regarded as high-order beliefs involving cognitive elements. Spontaneous concepts with strong emotional elements are called 'views'. In the literature, the use of the terms beliefs, concepts, views and attitudes varies according to the discipline, perspective and researcher [Tob94; Paj92; Swa99].

Rationalism argues that true knowledge is not the product of sensory experience but of some ideal mental process. According to this view, there exists a priori knowledge that does not need to be justified by sensory experience. Rather, absolute truth is deduced from rational reasoning grounded in axioms. Mathematics is an example of this kind of reasoning. In contrast, empiricism claims that there is no a

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[2] In traditional epistemological accounts, knowledge must satisfy the following conditions. In order for an individual A to have knowledge of something (a proposition, hereafter P), the following are necessary and sufficient conditions for A's knowledge of P:

a) P is true (the truth condition);
b) A must believe that P is true (the belief condition); and
c) A's belief that P is true must be justified (the justification condition).

According to the first truth condition, an individual's knowledge of something does not exist unless its proposition is true. Therefore, a statement like 'I know P, but P is not true' is simply self-contradictory. A true proposition describes reality, which is true in the past, the present and the future. The belief condition requires not only that a statement must be true, but also that we must believe that the statement is true. While the truth condition is an objective requirement, the belief condition is a subjective requirement. Therefore, when we claim the knowledge of P, we must assume a certain attitude toward P. Assuming an attitude toward P means that we believe in P. Nevertheless, believing P is not a defining characteristic of P's truth. It is possible to say that 'I believe in P, but P is not true'; yet the proposition 'I know P is true, but I do not believe P is true' is a self-contradiction. In short, knowledge contains belief, but belief does not contain knowledge. The justification condition calls for evidence for proving the truthfulness of knowledge. Belief, which reveals an attitude toward P, does not justify P itself; it needs evidence of truth. Belief formed without valid evidence does not constitute knowledge, even though it could happen to be true in some circumstances. Plato, *Meno, Phaedo and Theaetetus* [Non95].

priori knowledge and that the only source of knowledge is sensory experience. According to this view, everything in the world has an intrinsically objective existence; even when one has an illusory perception, the very fact that something is perceived is significant. Experimental science is an example of this view. Thus the two dominant approaches to epistemology, rationalism and empiricism, differ sharply with regard to what constitutes the actual source of knowledge.

Another fundamental difference lies in the method by which knowledge is obtained. Rationalism argues that knowledge can be attained deductively by appealing to mental constructs such as concepts, laws or theories. Empiricism, on the other hand, contends that knowledge is derived inductively from particular sensory experiences.

In contrast to this Western philosophical tradition, the Japanese intellectual tradition is not as deeply rooted in the split between subject and object. Three distinctions have formed the foundation of the Japanese view towards knowledge of the Japanese intellectual tradition: (1) oneness of humanity and nature, (2) oneness of body and mind and (3) oneness of self and other.

Basic attitudes associated with the oneness of humanity and nature in Japanese epistemology can be found in the structural characteristics of the Japanese language. Physical and concrete images of objects are indispensable for Japanese expression; an essential epistemological pattern for the Japanese is to think visually and to manipulate tangible images [Kum90]. The inherent characteristics of the Japanese language reveal a unique view of time and space. The Japanese see time as a continuous flow of a permanently updated present. In contrast, Westerners have a sequential view of time and grasp the present and forecast the future by a historical retrospection of the past.

The oneness of humanity and nature found in the Japanese language and the flexible view of time and space illustrates a Japanese tendency to deal with sensitive emotional movements rather than to abide by any fixed worldview or metaphysics. This tendency determines the relationship between human thought and nature. The oneness of humanity and nature can complement the Cartesian separation of man and nature in which Western philosophical traditions are deeply rooted.

Another important intellectual tradition of Japan is the emphasis on the whole personality, the oneness of body and mind. For the Japanese, knowledge means wisdom acquired from the perspective of the entire personality. This is in stark contrast to the Western philosophical tradition of body-mind separation [Var91]. The Western philosophical tradition is compared by Yuasa with Japanese philosophy and is described as follows:

"Modern Western philosophy regards the problem of action, namely, that of the will, to be an issue for practical ethic, but not theoretical epistemology...This is because modern Western philosophy seeks human essence in rational, thinking subjects; its epistemology excludes the problem of body. This attitude obviously originates in the rationalistic view of the human being and from Descartes' mind-body dualism". [Yua87]

Western epistemology tends to accord the highest value to abstract theories and hypotheses which have contributed to the development of science. The backdrop of this tendency is the long tradition of valuing precise, conceptual knowledge and systematic sciences, which can be traced back to Descartes. In contrast, Japanese epistemology tends to value the embodiment of direct, personal experience. The two major traditions of the oneness of humanity and nature and the oneness of body and mind have led the Japanese to value the interaction between self and other. While most Western views of human relationships are atomistic and mechanical, the Japanese view is collective and organic. It is within the context of an organic worldview that the Japanese emphasize subjective knowledge and intuitive intelligence.

The structure of the Japanese language shows the sympathetic oneness of self and others. The ambiguous nature of the Japanese language thus requires one to be equipped with some tacit knowledge of context. For example, verbs in the Japanese language do not conjugate with the subject of the sentence; they are always used in the same form in all contexts. In the Indo-European languages, verbs basically conjugate with the subject because the meaning of a verb differs when used with a different subject. This sympathetic nature of the verb in Japanese implies that the perspective can be shared naturally and smoothly by the group and sometimes by society at large. It also means that it is difficult for the Japanese to express their own thoughts and feelings directly, for this approach, you and I are two parts of a whole (two sides of the same coin). While Western societies promote the realization of the individual self as the goal of life, the Japanese ideal of life is to exist harmoniously among others as a collective self. Japanese realize themselves in their relationship with others, and working for others means working for themselves. They see reality typically in the physical interaction with nature and other human beings. Although contemporary Western philosophy seems to be getting closer to the Japanese intellectual tradition emphasizing body and action, the view of knowledge in sciences is still dominated by the Cartesian dualism between subject and object, mind and body or mind and matter.

The distinct differences between Western and Japanese epistemologies lead to different interpretations of what is knowledge. Westerners have a view of knowledge as necessarily explicit knowledge, something formal and systematic. Explicit knowledge can be expressed in words and numbers and easily communicated and shared in the form of written and spoken language and hard data, scientific formula and codified procedures. Explicit knowledge can easily be processed by a computer, transmitted electronically or stored in databases. Japanese have a very different understanding of knowledge; they recognize that knowledge as being primarily tacit knowledge, which is something not easily visible or expressible. Tacit knowledge cannot be communicated and shared in a systematic or logical manner but has to be converted into words or numbers that everyone can understand. Tacit knowledge can be represented in two dimensions. The first is a technical dimension, which encompasses the kind of informal and hard to pin down skills or crafts captured in the term know-how. The second is an important cognitive dimension consisting of schemata, mental models, beliefs and perceptions so ingrained that we take them for granted. Therefore, scientific objectivity is not the sole source of knowledge. The most precious knowledge can neither be taught nor passed on. In fact, the most powerful learning comes from direct experience. Much of our knowledge is the fruit of our own purposeful endeavours in dealing with the world. A child learns to eat, walk and talk through trial and error [Lev91].

The distinction between explicit and tacit knowledge is key to understanding the differences between the Western and the Japanese approaches to knowledge and can be seen as complementary rather than as an either-or dichotomy. Neither the Japanese nor the Western methodology of knowledge creation provides the complete solution. In Western methodology, the interaction between tacit knowledge and explicit knowledge tends to take place mainly at the individual level. While the interaction between tacit knowledge and explicit knowledge takes place at the group level in the Japanese methodology, its tendency is to overemphasize the use of figurative language and symbolism at the expense of a more analytical approach and documentation. It is necessary to integrate the merits of both the Japanese and the Western methodologies to develop a universal model of organizational knowledge creation. This thesis brings together aspects of Kurki-Suonio's model with that of Nonaka's model of knowledge creation.

3.2 Knowledge creation in the learning process

Learning is an expanding perception process starting at birth. Perception refers originally to the creation of sensation from sensory excitation, which is the elementary process from which all-learning starts [Kur94a]. The perceptional approach[3], which is the pedagogical foundation of Kaarle Kurki-Suonio's study, states that learning is interpreted as a perception process, where the meanings of the concepts are created before the concepts themselves [Kur94b]. Concepts are processes, not products, and understanding arises from perception of the concepts, not from the concepts themselves. Perception is the primary creation of the concept's meaning; mental modelling or the individual understanding of nature calls for subsequent verbal conceptualization. Conceptualization leads to terminology, or language, which becomes a tool for further perception. In this way concepts add new material for the perception process and lead to a hierarchy of concepts of increasing generality and abstraction.

Science is a highly structured perception process [Kur92; Kur93; Kur94c]. Perception, learning, studying, research and science are different stages of the same process: the creation of knowledge, which is everyone's personal process. It is an inevitable conclusion that learning is not a logical process but an intuitive process and that knowledge attained by perception is permanent. Both learning and research are conducted and controlled by intuitive sensitivity, not by logical necessity.

According to the perceptional approach, understanding is based on perception of empirical meaning: a theory is a detailed quantitative representation of something that is understood. In this sense, observation and experiment form the basis of learning, where concepts are representations of nature as it is observed. Once the

[3] The perceptional approach constitutes the underlying framework of the physics teacher education programme at the University of Helsinki, Department of Physical Sciences and has been developed over 20 years. In Finland, this approach is the only substantial comprehensive, consistent, and well known collection of ideas about physics education.

meaning, instead of the formal representation, is understood to be the essence of a concept, the nature of a concept as an element of scientific knowledge is seen in a new light. The concepts do not exist without their meanings and the meanings cannot be separated from the process that creates them. Thus, concepts cannot be understood as the building blocks of a theoretical structure which maps on to the empirical structure of experimental results. The primary meanings of physical concepts stem from the in basic perception of the relevant class of phenomena and results in a mental model of causal relationships of the perceived vision as a whole.

Concepts in physics are characterized by the quantification of observable properties. The quantification is the threshold process that transforms observable properties and their relationships into quantities and laws. Above the levels of quantities and laws there is the level of quantitative understanding, where the laws are combined into theories and models. Therefore, the learning of knowledge in physics, a crucial point of this thesis, includes, in addition to normal conceptual development, a quantification process. This threshold process transforms qualitative appreciation into quantitative formalization and builds a structure of quantitative concepts on the foundation of the qualitative system. This makes physics, and science in general, different from other branches of learning.

The primary evidence and the main motivation for the development of Kaarle Kurki-Suonio's study comes from the observation that a vast majority of physics students understand science as an abstraction, without any relationship to nature, and that physics teaching reinforces this. In teaching and analysis of the historical development of science, many examples demonstrate that perceptional approach and perceptional experimentalism are necessary in teaching. It is not enough just to demonstrate and explore phenomena. Students must be able to do qualitative experimentation first and then to build causal, mental images into laws and further experiments as tests of the laws discovered. Kurki-Suonio's study focuses on creating knowledge through interaction between nature and the human mind, starting from the hypothesis that this interaction has a fractal or self-similar structure, repeated in all hierarchical levels of the development of science and learning. Fractal or self-similar structure means that the dynamic basic features of this model are repeated at different scales of the process: from the elementary processes of perception to the interaction of the experimental and theoretical research approaches and to the interaction of science and technology.

In physics, a Cartesian dualism prevails between empiry (an empirical approach) and theory.[4] From the empirical standpoint, physics is experimental research into nature; from the standpoint of theory, physics is a mathematical structure. Traditionally, separating dualism has prevailed in teaching and researching physics. According to unifying dualism, the observation and the mind, or the experiment and theory, are inseparably coupled. There are neither purely experimental experiments nor purely theoretical theories. Separate experimental and theoretical processes do not drive the science, but perception is rather one single expanding process [Kur91; Häm98]. The basis for empirical conceptualization is the understanding of a concept through empirical perception, which includes the development process that creates the meaning of the concept. The meanings of concepts are created by a continuous process, which is fundamentally steered from perception to theory. Every physical concept is a process in which experiment and theory are joined into one constantly developing concept formation.

Therefore, conceptualization in science is neither purely a mental process nor a purely observational one. Similarly, science is the interaction between theory and experiment in a process of continuous refinement. Theories constructed from the basis of current knowledge are tested by experiment and the resultant understanding is then used to refine or discard theories. Every concept, quantity, law or theory has its empirical basis, which forms the core of its meaning.

3.2.1. Scientific, technological, and social processes

According to Galileo Galilei, ‘how’ is the only way to approach the question ‘why’ [Häm98]. Understanding and use are the two basic motives of the knowledge creation process. Both have to answer the questions why and how (Fig. 3.1). They divide the process into two bi-directional branches: the scientific process and the technological process, which are two different types of interaction of nature and the human mind or empiry and theory. Both can be studied on the basis of separating dualism or unifying dualism.

[4] Empiry: observation and experimentation. Palmer uses the term to embrace both classes of scientific activity; Empiry is the counterpart of theory [Pal98].

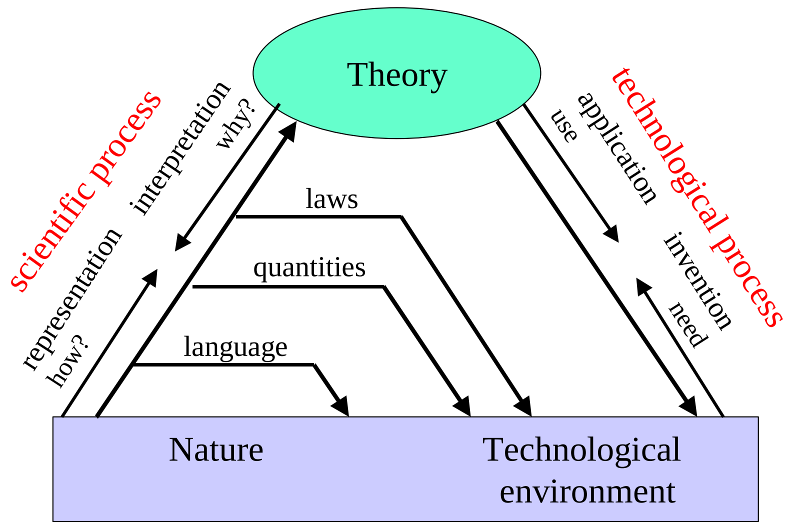

Fig. 3.1: Basic processes of knowledge creation within the learning process [Häm98].

The primary sub-process of the scientific process, moving from nature to theory, is the representation that forms the whole-perceived vision from the excitation of senses to the formed mental pictures understood to describe real entities and phenomena and their properties. The secondary sub-process of the scientific process, steered from theory to nature, is interpretation, controlled by hypotheses, predictions, verifications, and falsifications. The primary sub-process of the technological process is application, steered from theory to the environment, and the secondary, from environment to theory, is invention. The scientific and technological processes are mutually dependent and inseparably interconnected. They have a definite primary direction of propagation, but their progress is based on the bi-directional dynamics maintained by the three opposing processes.

Nature and environment are connected in the sense that the environment is the part of nature that can be technologically manipulated, changed and improved. Thus, together the scientific and the technological processes form a loop mediated by a third branch, the social process, which is an interaction between individuals and groups extending individual cognition into shared understanding. This loop primarily rotates clockwise. All three processes are inseparably intertwined. Every concept contains a seed of application and has both a scientific and a technological meaning, agreed in the social process, which extends individual cognition into a shared social understanding and is necessary to create common concepts. This is not only a large-scale structure, but it is also a fractal or self-similar feature of the knowledge creation process. The presence of the three processes and their interconnections can be identified from the beginning. The entities, phenomena and properties perceived by a child as the start of the scientific process are never solely organizing the whole-perceived vision. They are loaded with practical applications, which the child is constantly taking into account and making use elsewhere. When a child, quite naturally and intuitively, adapts his or her behaviour and when the child searches his or her possibilities and limits through trial and error, that child is starting to develop the technological process. The significance of the social process, the child's interaction with his or her parents, is evident as the necessary condition for both child and parents.

The scientific process builds conceptions of the world aiming at an understanding of natural phenomena. The technological process changes the structure of the world to satisfy uses and needs. The social process negotiates the meanings to find agreement about procedures and results within both the scientific and technological processes. Technology products are the results of the technological process, whereas concepts and conceptual structures are the results of the scientific process. Inventions and unifying ideas, respectively, represent great achievements. The scientific process leads to the great unifying developments of physics, while the technological process is responsible for changes in the environment, living conditions and technological capability. Ultimately, the scientific and technological processes are the sources and driving forces of science and technology, which are interconnected.[5] Anyway, all these results have become possible only through agreement achieved in the social process.

All three processes must be taken into account to have a correct picture of the nature of concept formation. The roles and the relationship of the three processes, as well as the significance of all three in action, can be equally recognized in science and in learning. During planning and interpretation, the scientific process dominates, while controlling nature through the design and performance of the experiment requires the technological process. The social process, which discussion activates, governs both the scientific and technological processes.

3.2.2 Concept formation

In the learning process understanding must naturally come first. Concept formation (Fig. 3.2) is cumulative and leads to hierarchically layered and structured knowledge. The concepts of different hierarchical levels are not end products but active elements of the scientific process. The logic of conceptualization is a fractal, self-similar, bi-directional process which includes the three processes (scientific, technological and social), and the inseparability of these three processes, the movements in two directions from nature to theory and from theory to nature and the inseparability between these two movements. This means that all the basic features of the process structure are similar at any scale of the process and can be realized in all hierarchical levels.

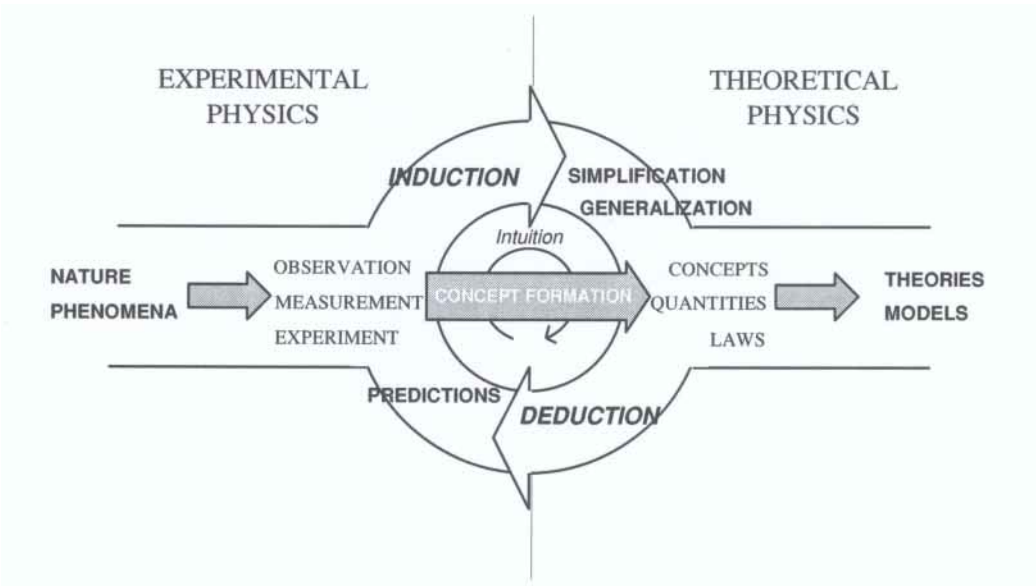

Fig. 3.2: Self-similar bi-directional logic of concept formation process [Häm98].

Fig 3.2 shows diagrammatically the self-similar logic of concept formation; induction and deduction are present at every level [Häm98]. There are three main approaches, involved in the learning processes starting from different parts of the clockwise cycle: the axiomatic-deductive approach, the empirical-inductive approach,

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[5] In the early development of the philosophy of technology as a discipline, one finds the opinion that technology is applied science. Bunge, for instance, speaks about technology and applied science as synonyms [Bun96].

and the perceptional approach. The first enters Fig. 3.2 from the right side. It is a thinking method for learning based directly on well-understood structures of knowledge; it emphasizes the importance of deductive reasoning and begins with theory. This approach requires the ability for abstract reasoning and assumes that the empirical meanings of theoretical concepts are already well known. The second approach is the opposite and enters Fig. 3.2 from the left. It starts by questioning nature, to understand, why. Its benefit is concreteness, in the sense that concepts already have an empirical meaning. Neither of these two approaches works alone. The perceptional approach enters Fig. 3.2 from the middle. It emphasizes the development history of the concepts and the importance of intuition. This approach tries to present a true picture of the experimental basis of concept formation and bases the structure of physical knowledge on unifying idea, the great achievements of the scientific process.

3.2.3 Hierarchical levels of conceptualization

All conceptualization in physics starts from basic perception. The transition from qualitative to quantitative methods and concepts gives the perception process a new dimension, which is characteristic of physics. Quantities form the basis for concept formation in physics. Quantities, laws and theories are the quantitative parallels of properties, phenomena and their resulting mental models. Quantities and laws introduced as formulas and equations are representations before there is anything to represent. In order to define a quantity it is necessary to go through the complete process that creates the meaning of the quantity. This process can be analysed in terms of stages or sub-processes related to the hierarchical levels of the conceptual structure of physics as shown in Fig. 3.3.

The aforementioned fractal, self-similar, bi-directional logic prevails at all levels of the conceptual structure of physics. The primary direction of the process is from concrete to abstract, from simple to structural, from observations through language, quantities and laws to theory. It puts the bi-directional dynamics of science into different positions: the experimental approach identified as the primary direction, and the theoretical approach as the opposite. The core of learning physics is the conceptualization of perceived empirical meanings. Therefore learning physics has the same natural direction as the conceptualization, from perception to conception and from experiment to theory.

The hierarchical levels of conceptualization represent different abstraction levels. In studying each topic, the level of language is the most important hierarchical level, because upper levels can only be reached through it. This means that the main boundary is between the first level and the other three, because the first implicitly contains the other three levels. This level lays the foundation for the scientific use of language. The level of quantities must be entered via quantification, which is based on a quantifying experiment. The connected level of laws is an abstraction, a mathematical presentation of the results of concrete experiments. The level of theories is the uppermost level. The theoretical meaning of a quantity comes about through structurization. This is the threshold process leading from the level of quantities and laws to the highest conceptual level of theories.

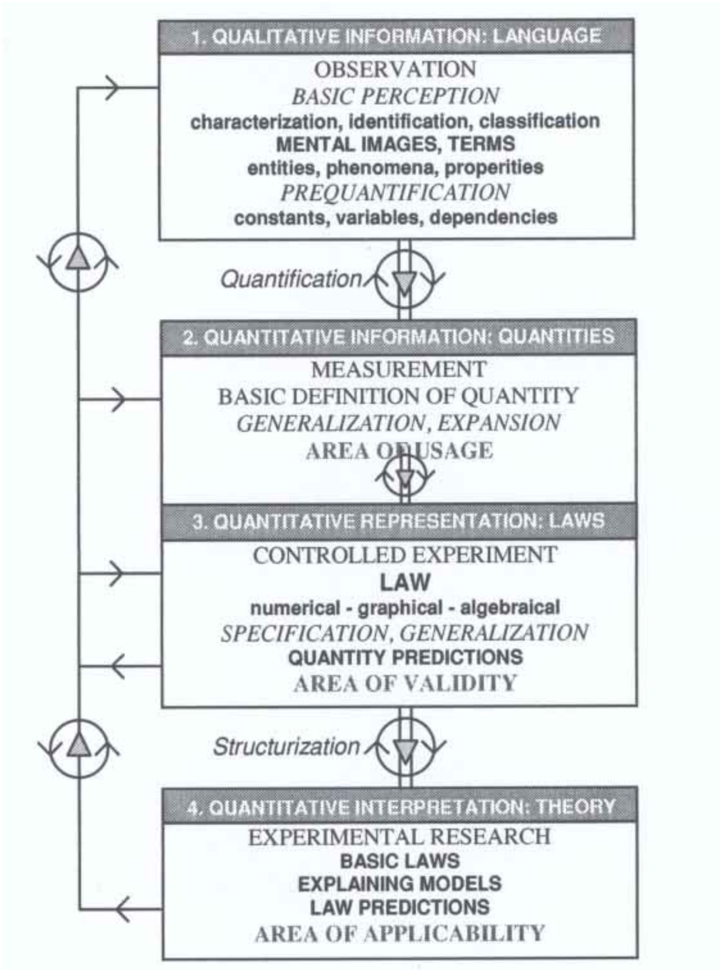

Fig. 3.3: Hierarchical levels of concepts in physics [Häm98].

The hierarchical level of quantities controls the order in which quantities can be introduced. The definition of a quantity is always based on a law that is in turn based on previously defined quantities. Introduction of a quantity is thus possible only if these other quantities, lower in the hierarchy, are already known. The structure of the quantity system of physics means that a rigid hierarchy prevails in the relationship of quantities, whereas the qualitative level of physics has a much less rigid hierarchical structure. This hierarchical structure forms another spiral where the quantitative level of concepts is necessary to build up the basic perception of the next level of qualitative appreciation of new phenomena.

3.3 Knowledge creation in an organizational context

Studies of organizational culture have been able to shed light on the organization as an epistemological system. They have underscored the importance of such human factors as values, meanings, commitments, symbols and beliefs, and paved the way for more elaborate research on the tacit aspects of knowledge. Furthermore, they have recognized that the organization, as a shared meaning system, can learn, change itself and evolve over time through social interaction among its members.

A new paradigm of corporate strategy has emerged to help organizations compete more effectively in the ever-changing global environment. The dynamic nature of strategy has led to the concept of dynamic capabilities, or the ability of an organization to learn, adapt, change and renew over time, which involves problem finding and problem solving at the organizational level [Tee91]. A learning organization is a place where people are continually discovering how they create reality and how they can change it [Sen90]. In this era of turbulent economies and accelerated technological change organizations, just as individuals, must always confront new circumstances [Coh91]. It is widely agreed that learning consists of two kinds of activity. The first kind of learning is obtaining know-how in order to solve specific problems based upon existing premises. The second kind of learning is establishing new premises (i.e., paradigms, schemata, mental models or perspectives) to override existing ones. The creation of knowledge clearly involves interaction between these two kinds of learning, and this interaction forms a kind of dynamic spiral.

Organizations can transform and recreate themselves by destroying the existing knowledge system and by inventing new ways of thinking and doing.

Creating new knowledge is not simply a matter of learning from others or acquiring knowledge from outside. Knowledge has to be built on its own, frequently requiring intensive and laborious interaction among members of the organization. The organization cannot create knowledge on its own without individual initiative and group interaction. The organization has to provide a context in which individuals can interact. In other words, knowledge cannot be created without intensive outside-inside interaction. The organization that wishes to cope dynamically with the changing environment needs to create information and knowledge, not merely process information and knowledge efficiently. Furthermore, organizational members must not be passive, but must rather be active agents of innovation. All play a part and have responsibility for creating new knowledge. An individual's personal knowledge is transformed into organizational knowledge valuable to the organization as a whole.

Ikugiro Nonaka's study focuses on knowledge sharing and knowledge transfer inside an organization, and gives rise to an overall view of the organization not as a machine for processing information, but as a living organism in which everyone is a knowledge worker [Non95].

Although the terms 'information' and 'knowledge' are often used interchangeably, there is a clear distinction between the two. Information is a medium or material for eliciting and constructing knowledge and affects knowledge by adding something to it or reconstructing it [Mac93].[6] Knowledge is identified with information produced or sustained belief [Dre81]. There are three observations that illustrate the similarities and the differences between information and knowledge. First, knowledge, unlike information, is about beliefs and commitment. Knowledge is a function of a particular stance, perspective or intention. Second, knowledge, unlike information, is about action. It is always knowledge to some end. And third, knowledge, like information, is about meaning. Thus information is a flow of messages, while knowledge is created by that very flow of messages, being anchored in the beliefs and commitment of its holder. This understanding emphasizes that knowledge is essentially related to human action. Both information and knowledge

[6] Information can be viewed from two perspectives: syntactic and semantic information. An illustration of syntactic information is found in Shannon's analysis of information flow measured without any regard to inherent meaning [Sha49]. The semantic aspect of information is more important for knowledge creation, as it focuses on conveyed meaning. Any preoccupation with the formal definition of information leads to a disproportionate emphasis on the role of information processing, which is insensitive to the creation of new meaning from the chaotic, equivocal sea of information and cannot capture the real importance of information in the knowledge creation process.

are context-specific and relational in that they depend on the situation and are created dynamically by social interaction among people.

As a fundamental basis to explain how to realize innovation, Ikujiro Nonaka's theory of organizational knowledge creation focuses on the subjective nature of knowledge represented by such terms as commitment and belief, which are deeply rooted in individuals' value systems. Knowledge is considered as a dynamic human process of justifying personal belief towards the 'truth'. The dynamic process of knowledge creation is anchored to a critical assumption that human knowledge is created and expanded through social interaction between tacit knowledge and explicit knowledge, and that it describes how knowledge is created and how the knowledge creation process is managed. This interaction, called knowledge conversion, is a social process between individuals and not confined within one individual. Through this social conversion process, tacit and explicit knowledge expand in terms of both quality and quantity [Non90]. The knowledge creation process of making tacit knowledge explicit has three key characteristics. First, heavy reliance is placed on figurative language and symbolism to express understanding. Second, to disseminate knowledge an individual's personal knowledge has to be shared with others. Third, new knowledge is born in the midst of ambiguity and redundancy.

3.3.1 Two dimensions of knowledge creation

The theoretical framework of organizational knowledge creation contains two dimensions of knowledge formation: the epistemological and the ontological. The epistemological dimension is where conversion takes place between tacit knowledge and explicit knowledge; the ontological is where knowledge created by individuals is transformed into knowledge at the group and organizational levels.

The epistemological dimension is based on the distinction between tacit knowledge, which is personal, context-specific and therefore hard to formalize and communicate, and explicit knowledge, which is transmittable in formal and systematic language. Tacit knowledge is created here and now in a specific, practical context. Explicit knowledge is about past events or objects there and then. It is precisely during the conversion from tacit to explicit and back to tacit knowledge that organizational knowledge is created. Knowledge creation fuels innovation. In other words, the process by which new knowledge is created within the organization – in the form of new products, services or systems – becomes the cornerstone of innovative activity. The key to a successful innovation process lies in the mobilization and conversion of tacit knowledge into explicit knowledge.

The ontological dimension is concerned with the levels of knowledge-creating entities: individual, group, organizational and interorganizational. In a strict sense only individuals create knowledge and an organization cannot create knowledge without them. Organizational knowledge creation is a process that amplifies the knowledge created by individuals and crystallizes it as a part of the organization knowledge network. In this process the organization provides the context for interaction among individuals across intra- and interorganizational levels to create knowledge. Thus knowledge creation includes not only innovation but also learning which that can shape and develop approaches to daily work.

3.3.2 Four modes of knowledge conversion

The conversion between tacit and explicit knowledge is carried out through four different modes, experienced by the individual: (1) socialization (tacit knowledge to tacit knowledge), (2) externalization (tacit knowledge to explicit knowledge), (3) combination (explicit knowledge to explicit knowledge), and (4) internalization (explicit knowledge to tacit knowledge).

Socialization is the process of sharing experiences and thereby creating tacit knowledge such as shared mental models and technical skills, through observation, imitation and practice. The key to acquiring tacit knowledge is experience. Without some shared experience (for example brainstorming, informal meetings and discussion) motivated by a search for meaning, it is extremely difficult for one person to project her or himself into another individual's thinking process.

Externalization is the process of articulating tacit knowledge into explicit concepts and is typically seen in the process of concept creation triggered by dialogue or collective reflection. This mode holds the key to knowledge creation because it creates new, explicit concepts from tacit knowledge. It may however be difficult to find adequate verbal expression for a mental image through the use of analytical methods of deduction or induction alone. Metaphor or analogy, which are distinctive methods of perception, often drives externalization.[7] Using an attractive metaphor or analogy is highly effective in fostering direct commitment to the creative process in the early stages of knowledge creation.

Combination is a process of systematizing concepts into a knowledge system. This mode of knowledge conversion involves combining different bodies of explicit knowledge. Individuals exchange and combine knowledge through such media as documents, meetings, telephone conversations or computerized communication networks. Reconfiguration of existing information through the sorting, adding, combining and categorizing of explicit knowledge (as conducted in computer databases) can lead to new knowledge. Knowledge creation carried out in formal education and training at school usually takes this form. The wide use of different technologies has resulted in many initiatives being focused within the combination mode.

Internalization is a process of embodying explicit knowledge in tacit knowledge. It is closely related to learning by doing. When experience through socialization, externalization and combination are internalized into individuals' tacit knowledge bases in the form of shared mental models or technical know-how, they become valuable assets. For organizational knowledge creation to take place the tacit knowledge accumulated at the individual level needs to be socialized with other organization members, to start new knowledge creation. The internalization mode helps if knowledge is verbalized or drawn into documents or oral presentations to facilitate the individual internalization and enriching of tacit knowledge as well as the transfer of explicit knowledge to other people. For example, reading or listening to a success story makes some members of the organization feel the realism and essence of the story; the experience that took place in the past may change into a tacit mental model. When most members of the organization share such a mental model, this tacit knowledge becomes part of the organizational culture.

Organizational knowledge creation is a continuous and dynamic interaction between tacit and explicit knowledge; innovation emerges thanks to this interaction. Each mode of knowledge conversion creates a different part of the knowledge and

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[7] Metaphor and analogy are often confused. The association of two things through metaphor is driven mostly by intuition and holistic imagery and does not aim to find differences between them. On the other hand, association through analogy is carried out by rational thinking and focuses on structural or functional similarities between two things and hence their differences. Thus analogy helps us to understand the unknown through the known and bridges the gap between an image and a logical model.

these interact with each other in the spiral of knowledge creation. Each mode respectively creates: sympathized knowledge, conceptual knowledge, systemic knowledge and operational knowledge. This interaction is shaped by shifts between different modes of knowledge conversion, which are in turn induced by several triggers. First, the socialization mode usually starts with building fields of interaction which facilitate the sharing of people's experiences and mental models. Second, dialogue or collective reflection using metaphor or analogy to articulate hidden tacit knowledge triggers the externalization mode. Third, networking newly created knowledge and existing knowledge from other parts of the organization, thereby crystallizing them into a new product, service or managerial system, triggers the combination mode. Finally, learning by doing triggers internalization.

3.3.3 Two spirals of knowledge

The organization has to mobilize tacit knowledge, the basis of organizational knowledge creation, created and accumulated at the individual level. The mobilized tacit knowledge is amplified through the four modes of knowledge conversion and crystallized at higher levels of the ontological dimension. Interaction between tacit knowledge and explicit knowledge at the epistemological dimension moves through all the levels of the ontological dimension starting at the individual and continuing through to the organizational boundaries, becoming ever larger in scale. The process leads to different cycles of knowledge creation. That process is dynamic and produces two different kinds of knowledge spirals.

The first spiral takes place at the epistemological dimension across the four modes of knowledge (Fig. 3.4). Another spiral takes place at the ontological dimension, where knowledge developed at the individual level is transformed into knowledge at the group and organizational levels (Fig. 3.5). Although each dimension produces a dynamic spiral, the truly dynamic nature of Nonaka's theory can be depicted as the interaction of these two knowledge spirals over time. In a three-dimensional chart (with time as the third dimension), the knowledge spiral at the epistemological dimension rises upwards, whereas the knowledge spiral at the ontological dimension moves from left to right and back to the left in a cyclical motion.

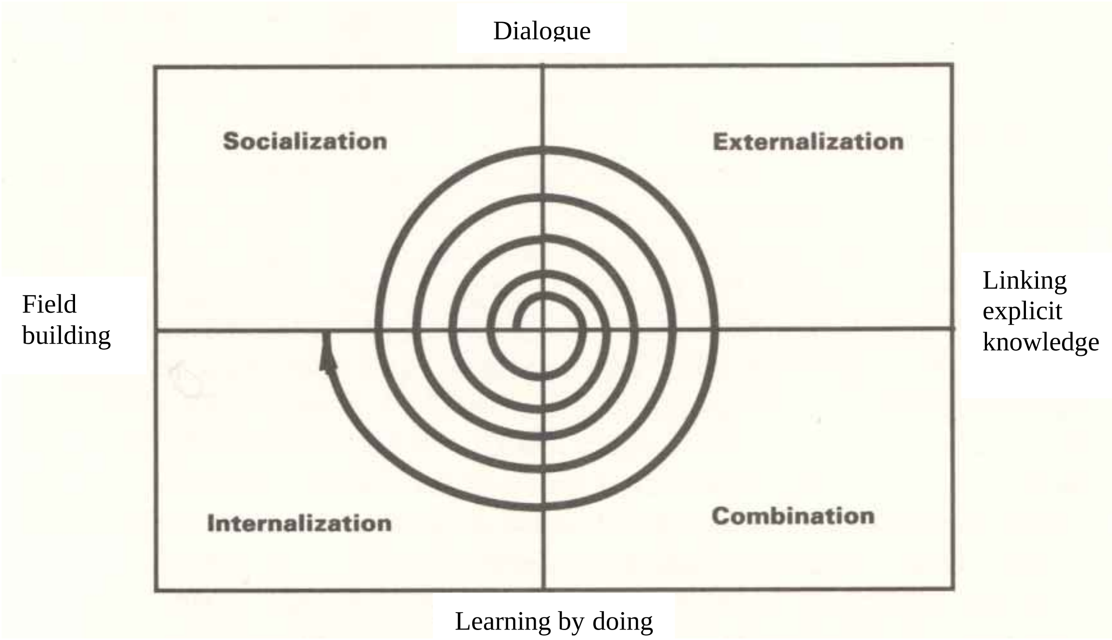

Fig. 3.4: The knowledge creation spiral at the epistemological dimension [Non95].

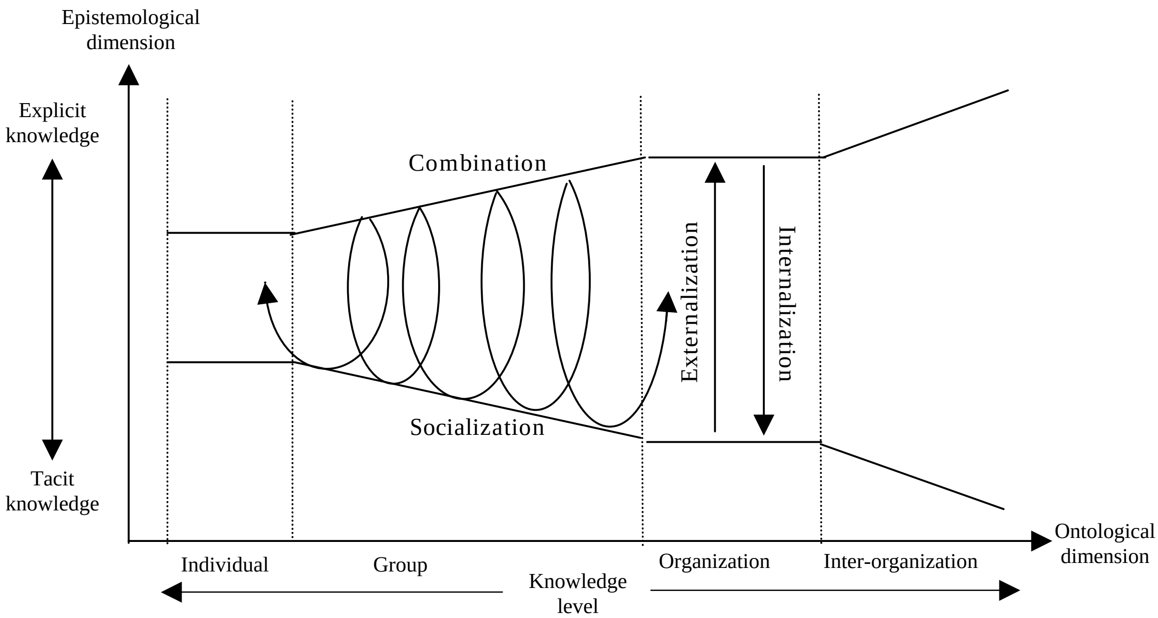

Fig. 3.5: The knowledge creation spiral at the ontological dimension [Non95].

The four modes of knowledge conversion are not independent of each other, but interact continuously when time is introduced. At the epistemological dimension, these interactions produce a five-condition knowledge spiral process, which enables the four modes to be transformed into this knowledge spiral. Neither are the organizational levels independent of each other, but interact continuously when time is introduced. At the ontological dimension, these interactions produce another five-phase knowledge creation spiral process, when knowledge developed at, for example, the project-team level is transformed into knowledge at the divisional level and eventually at the inter-organizational level.

3.3.5 Five conditions of the knowledge spiral process at the epistemological dimension

The five conditions of the knowledge spiral process at the epistemological dimension are intention, autonomy, fluctuation and creative chaos, redundancy and requisite variety.

The knowledge spiral is driven by organizational intention. Efforts to achieve the intention take the form of a strategy to develop the organizational capability to acquire, create, accumulate and exploit knowledge. The second condition for promoting the knowledge spiral is autonomy. At the individual level, all members of an organization should be allowed to act autonomously as far as circumstances permit. Autonomy increases the chance of unexpected opportunities arising and the possibility that individuals will motivate themselves to create new knowledge. Original ideas emanate from autonomous individuals, diffuse within a team and then become organizational ideas.

The third condition is fluctuation and creative chaos, which stimulates interaction between the organization and the external environment. Fluctuation is different from complete disorder and is characterized by order without recursiveness whose pattern is at first hard to predict [Gle87]. When fluctuation is introduced into an organization, its members face a breakdown of routine, habits or cognitive frameworks, and the opportunity to reconsider their fundamental thinking and perspective and to hold dialogue as a means of social interaction to create new concepts and knowledge. Some have called this phenomenon creating order out of noise or order out of chaos.[8]

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[8] According to the principle of order out of noise, the self-organizing system can increase its ability to survive by purposefully introducing such noise into itself [Foe84]. Order in the natural world includes not only the static and crystallized order in which entropy is zero but also the unstable order in which new structures are formed by the work of matter and energy. The latter is order out of chaos according to the theory of dissipative structure [Pri84]. In an evolutionary planning perspective, moreover, Jantsch argues: “In contrast to widely held belief, planning in an evolutionary spirit therefore does not result in the reduction of uncertainty and complexity, but their increases. Uncertainty increases because the spectrum of options is deliberately widened; imagination comes into play” [Jan80]. Researchers who have developed the chaos theory have found the creative nature of chaos [Gle87; Wal92]. Nonaka also applied the chaos theory to management [Non88; Zim93].

Chaos is generated naturally when the organization faces a real crisis. It can also be generated intentionally when the organization's leaders try to evoke a sense of crisis among organizational members by proposing challenging goals. This intentional creative chaos increases tension within the organization and focuses the attention of organizational members on defining the problem and resolving the crisis situation.

This approach is in sharp contrast to the information-processing paradigm, in which a problem is simply given and a solution found through a process of combining relevant information based on a preset algorithm. Such a process ignores the importance of defining the problem. To attain definition, a problem must be constructed from the knowledge available at a certain point in time and context. Anyway, the benefits of creative chaos can only be realized when organizational members are able to reflect upon their actions. Without reflection, fluctuation tends to lead to destructive chaos. To make chaos truly creative, the knowledge creating organization is required to institutionalize this reflection-in-action, which induces and strengthens the subjective commitment of individuals.

Redundancy is the fourth condition that enables an organizational knowledge spiral. Redundancy means the existence of information that goes beyond the immediate operational requirements of organizational members. For organizational knowledge creation to take place a concept created by an individual or group must be shared by others, who may not need the concept immediately. Sharing redundant information promotes the sharing of tacit knowledge, because individuals sense what others are trying to articulate. In this way, redundancy of information speeds up the knowledge creation process. Redundancy is especially important in the concept development stage, when it is critical to articulate images rooted in tacit knowledge. At this stage, redundant information enables individuals to invade each other's functional boundaries and offer advice or provide new information from different perspectives. Redundancy of information brings about learning by intrusion into each individual's sphere of perception. Even within a strictly hierarchical organization, redundant information helps to build unusual communication channels and to facilitate interchange between people's hierarchy and non-hierarchy.

There are several ways to build redundancy into organization. One is to adopt the overlapping approach, in which different functional departments work together in a fuzzy division of labour [Tak86]. Another is to divide the product development team into competing groups: each group develops a different approach to the same project and then the groups come together to argue over the advantages and disadvantages of their proposals. Another way is through a strategic rotation of personnel, especially between vastly different areas of technology or functions such as R&D and marketing. Such rotation helps organizational members understand their business from multiple perspectives, thereby making organizational knowledge more fluid and easier to apply. It also enables the diversification of skills and information sources. The extra information held by individuals across different functions helps the organization to expand its knowledge creation capacity. Redundancy of information increases the amount of information to be processed: it can lead to information overload and increase the cost of knowledge creation, at least in the short run. Therefore, a balance between the creation and processing of information is needed. One way to deal with the possible downside of redundancy is to make clear where information can be located and where knowledge is stored within the organization.

The fifth condition that helps to advance the knowledge spiral is requisite variety. An organization's internal diversity must match the variety and complexity of the external environment in order to deal with challenges posed by its environment [Ash56]. Organizational members can cope with many contingencies if they possess requisite variety, which can be enhanced by combining information differently, flexibly and quickly and providing equal access to information throughout the organization. To maximize variety, everyone in the organization should be assured of direct and rapid access to the widest variety of necessary information [Num89].

3.3.4 Five phases of the knowledge spiral process at the ontological dimension

The five phases of the spiral process at the ontological level are sharing of tacit knowledge, creating concepts, justifying concepts, building an archetype and cross levelling of knowledge (Fig. 3.6).

Organizational knowledge creation starts with the sharing of tacit knowledge, which corresponds to socialization, as the rich and untapped knowledge that resides in individuals must first be amplified within the organization. But tacit knowledge cannot be communicated or passed to others easily, since it is acquired primarily through experience and is not easily expressible in words. Thus, the sharing of tacit knowledge among multiple individuals with different backgrounds, perspectives and motivations becomes critical for organizational knowledge creation.

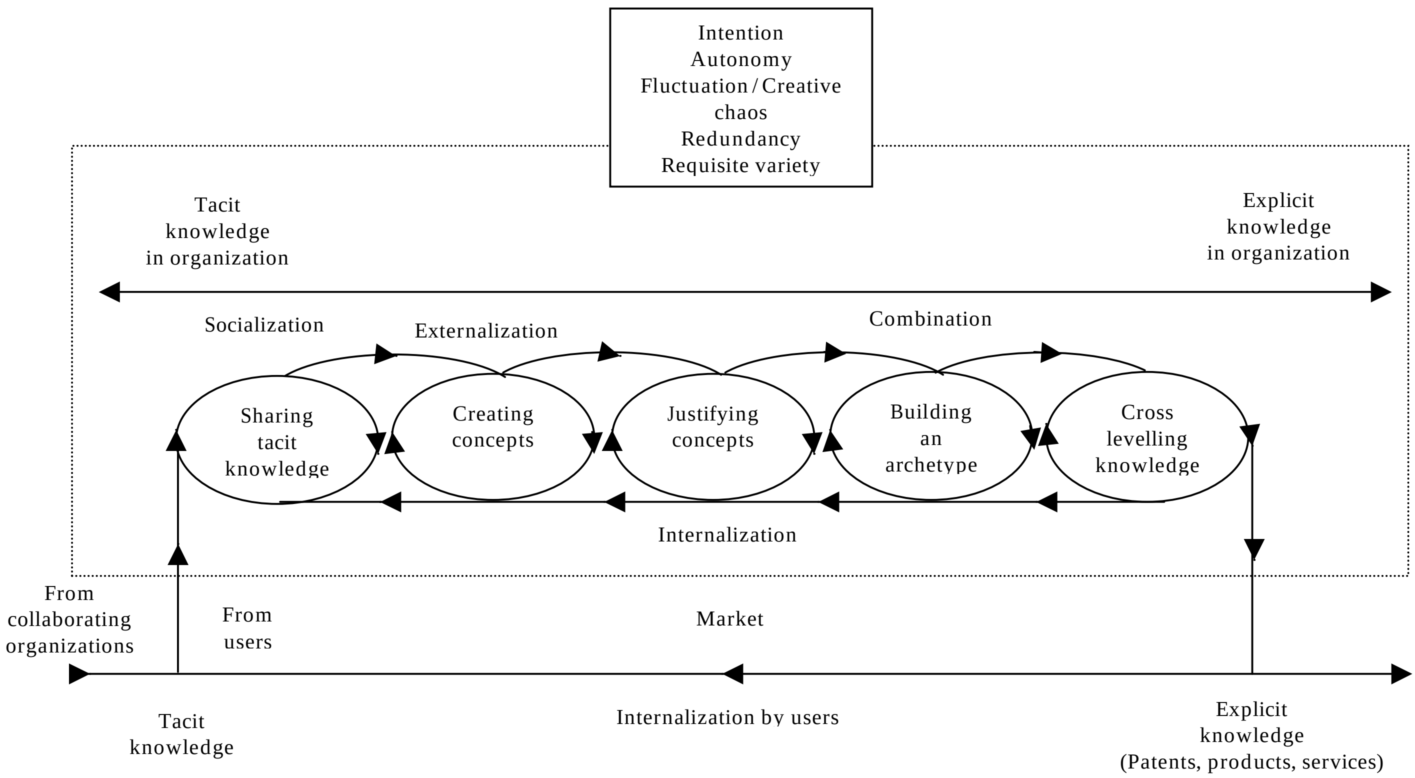


Fig. 3.6: Five-phase organizational knowledge creation process [Non95].

Individuals' emotions, feelings and mental models have to be shared to build mutual trust. To effect that sharing individuals from various functional separate organizational parts need space to interact with each other through dialogue and to work together to achieve a common goal. The requisite variety of the members, who experience redundancy of information and share their interpretations of organizational intention, facilitates organizational knowledge creation. Management injects creative chaos by setting challenging goals and endowing team members with a high degree of autonomy. An autonomous team starts to set its own task boundaries and begins to interact with the external environment, accumulating both tacit and explicit knowledge.

In the second phase, tacit knowledge shared through interaction is verbalized into words and phrases and finally converted and crystallized into explicit knowledge through creating concepts co-operatively by dialogue. This process, which corresponds to externalization, is facilitated by the use of multiple reasoning methods such as deduction, induction and abduction, employing figurative language such as metaphors and analogies. Autonomy helps team members to diverge their thinking freely, and then to converge it. To create concepts, members have to fundamentally rethink their existing premises. Requisite variety helps in this regard by providing different angles or perspectives for a problem. Fluctuation and chaos, either from the outside or inside, also help members to change their way of thinking. Redundancy of information enables members to understand figurative language better and to crystallize a shared mental model. In the theory of organizational knowledge creation, knowledge is defined as justified true belief. Therefore, justifying concepts is the third phase, in which the organization determines whether the new concept is truly worth pursuing. It is similar to a screening process and corresponds to internalization. Individuals seem to be justifying or screening information, concepts or knowledge continuously and unconsciously throughout the entire organizational knowledge creation process. The organization, however, must conduct this justification more explicitly to ensure the organizational intention is still intact and to ascertain whether the concepts being generated meet the needs of society at large. The most appropriate time for the organization to conduct this screening process is immediately after the concepts have been created. To avoid any misunderstanding of the organization's intention, redundancy of information helps to facilitate the justification process.

Having been justified, the concepts are then converted in the fourth phase of building an archetype that is tangible or concrete. It can take the form of a prototype in the case of hard product development, or an operating mechanism in the case of soft innovations, such as a novel managerial system or organizational structure. In either case, the archetype is built by combining newly created explicit knowledge with existing explicit knowledge.

In building a prototype the explicit knowledge to be combined could take the form of technologies or components. Because justified concepts, which are explicit, are converted into archetypes, which are also explicit, this phase is akin to combination. This phase is complex, therefore dynamic co-operation of various departments within the organization is indispensable. Both requisite variety and redundancy of information facilitate this phase. Organizational intention also serves as a useful tool for converging the various kinds of know-how and technologies that reside within the organization, as well as for promoting interpersonal and interdepartmental co-operation. On the other hand, autonomy and fluctuation are generally not especially relevant at this stage of the organizational knowledge creation process.

A knowledge-creating organization does not operate in a closed system but in an open system, in which knowledge creation is a never-ending process, upgrading itself continuously, and in which knowledge is constantly exchanged with the outside environment. The last phase extends the created knowledge across all the organizational divisions (intraorganizationally by horizontal and vertical cross fertilization) or outside (interorganizationally through dynamic interaction) in what is termed cross levelling of knowledge. For this phase to function effectively, it is essential that each organizational division has the autonomy to take the knowledge developed somewhere else and apply it freely across different levels and boundaries. Internal fluctuation such as the frequent rotation of personnel, redundancy of information and requisite variety all facilitate this knowledge transfer.

The nature of the knowledge conversion behind the dynamic and interactive process occurring within the two knowledge creation spirals is the key to understanding knowledge formation. The starting point in building a knowledge conversion is to recognize the need to transcend beyond dichotomies. For example, tacit knowledge and explicit knowledge, as well as an individual and an organization, are not opposing ends of two dichotomies but are mutually complementary entities, interacting dynamically and simultaneously with each other to create a synthesis, which is something new and different. The individual is the creator of knowledge and the organization is the amplifier of knowledge, and the context in which much of the conversion takes place is within the groups or team, which functions as the synthesizer of knowledge. The essence of knowledge creation is deeply rooted in building and managing synthesis through a knowledge conversion process. It is this dynamic and interactive process that fuels innovation.

3.4 Social capital, knowledge acquisition, and competitive advantage in young technology-based firms

This thesis analyses the associations between knowledge acquisition and competitive advantage for CERN and its users. It is related to a study on entrepreneurial high-technology ventures based in the UK, which examined the associations among social capital, knowledge acquisition and competitive advantage in young, technology-based firms' relationships with their key customers [Aut01]. Social capital is represented by social interaction, relationship quality and network ties. Social interaction refers to the extent of social relationships between the staff of the focal firm and key customer [Nah98]. Relationship quality refers to the extent that the development of goodwill, trust and expectations of reciprocity mark this interaction [Dey98]. Customer network ties denote the extent to which the key customer provides the focal firm with access to a broader set of customers [McE99]. Invention development and technological distinctiveness represent competitive advantage. The model, tested by mail survey data from 180 young, technology-based firms in the UK detailed how aspects of social capital embedded young, technology-based firms relationships with key customers increased their knowledge acquisition and how this knowledge acquisition enhanced competitive advantage through new product creation, enhanced technological distinctiveness and reduced sales costs.

Building on social capital and knowledge based theories [Kog92; Gra96; Spe96] the study suggested that social capital facilitates knowledge acquisition in key customer relationships, and that this knowledge leads to competitive advantage. By building relation specific assets, knowledge sharing routines and effective relational mechanisms into relationships, firms can use these relational resources for knowledge acquisition. Generating knowledge is the core competence of organization members and survival in high technology sectors demands that knowledge is continually and rapidly replenished [Lan98]. Acquired knowledge may be converted to competitive advantage: firms that acquired greater technological knowledge through key customer relationships produced a greater number of inventions and developed greater technological distinctiveness [Kog92].

This study posited that social interaction, relationship quality and customer network ties are positively associated with knowledge acquisition, and that knowledge acquisition is positively associated with competitive advantage for young technology-based firms. Moreover, the study found that knowledge acquisition is positively related to invention development and technological distinctiveness. The positive association between social interaction and knowledge acquisition is consistent with the assumption that learning, particularly learning involving difficult to transfer information, is aided by intensive, repeated interaction. Furthermore, key customers aid knowledge acquisition by providing introductions to other research centres and their knowledge bases. Indeed, access to diverse knowledge bases expands learning opportunities and aids development of knowledge integration skills. Knowledge acquisition can be identified as a mechanism through which inter organizational relationships benefit invention development.

Although the positive relationship between knowledge acquisition and technological distinctiveness is consistent with the learning framework, some researchers have argued that organization members are in danger of losing creativity[9] if they become too dependent on one or few customers [Chr97]. This is consistent with the finding that effective governance in inter-organizational relationships improves the efficiency of exchange [Dye98]. Exposure to a variety of customers enhances young technology-based firms' ability to assess and value the knowledge available from the key customer. Increases in knowledge integration skills strengthen other core competencies and may therefore lead to greater effectiveness in a variety of domains. Diversity of contact is key to increasing the breadth, depth and speed of an entrepreneurial firm's learning: exposure to a diversity of external contacts increases the firm's learning by doing, increasing new knowledge integration skills and thereby the speed and depth of subsequent technological learning [Zha00].

[9] The need for creative thinking arises from the limitations of the behaviour of the mind as a self-maximizing memory system [DeB70]. Therefore, different idea generation techniques or models to promote creative thinking are valuable in ideation [Smi98]. Consequently, outcomes of creative problem solving activities depend on the creative processes and ideation techniques learned and applied. Attitudes (interest, motivation and confidence), cognitive ability (knowledge, memory and thinking skill) and experience (familiarity with content, context and strategies) are additional factors that influence the problem solving process [Fis90].

Another study has proposed that the process of learning converts inter-organizational interaction into technical competencies [Ste96]. Knowledge acquisition is a key mechanism through which collaboration leads the development of technical competencies. The fact that some direct effects of customer ties on technological distinctiveness remain after accounting for knowledge acquisition from the key customer suggests that organization members learn from secondary sources, and supports the view that knowledge diversity helps to create competitive advantage.

From a practical point of view, the study indicates that key customer relationships offer significant learning opportunities for young, technology-based firms [Aut01]. Entrepreneurs may be able to actively manage their organization members' social capital to stimulate knowledge acquisition and build competitive advantage. Similarly, those young technology-based firms should at a minimum be aware of the potential downsides of building social capital and relying on a key customer for external knowledge. Finding the optimal level of social capital is therefore a challenge for entrepreneurs. The results of the study provide evidence that knowledge acquisition plays a mediating role between social capital and competitive advantage [Aut01]. This means that the knowledge acquired from these sources, in particular from social interaction and network ties, may then be transformed into competitive advantage via enhanced technological distinctiveness, invention development and sales cost efficiency.

3.5 Knowledge creation path: from the individual learning process to organizational knowledge acquisition and transfer

In what follows, a new model of knowledge creation, acquisition and transfer in a research organization is developed, on the basis of the above considerations, for the needs of this study.

Human knowledge is created and expanded through social interaction between tacit and explicit knowledge. Only individuals can create knowledge. An organization as such cannot create knowledge. It is, therefore, very important for an organization, such as CERN, to support and stimulate the knowledge creating activities of individuals and to provide the appropriate context for them. Organizational knowledge creation should be understood as a process that organizationally amplifies the knowledge created by individuals and crystallizes it at the group level through dialogue, discussion, experience sharing or observation. Organizations have to provide a context in which individuals can hold a dialogue, which may involve considerable conflict and disagreement. It is precisely such a conflict that pushes individuals to question premises and to make sense of their experience in a new way. Furthermore, organizations such as CERN aid knowledge acquisition by providing and improving relationships with other research centres and their knowledge bases, expanding opportunities in the development of knowledge integration skills. Organization members are in danger of losing creativity and innovation if they become too dependent on CERN and just one or few other centres. This kind of dynamic internal and external interaction facilitates the transformation of individual knowledge into organizational knowledge, which can fuel innovation, leading to competitive advantage via enhanced technological distinctiveness and invention development.

Cartesian dualism is the working hypothesis of Kurki-Suonio’s approach regarding individual knowledge creation, while the framework of Nonaka’s approach, focusing on organizational knowledge acquisition, is the Japanese cultural tradition, where this dualism plays no role. The intention of the author of this thesis is to absorb into a new model the strengths of the two different approaches in order to describe the entire knowledge acquisition process, from creation to transfer, in a research organization, CERN, in which scientific knowledge is acquired.

In studying the two theoretical approaches, the author observed that in Kurki-Suonio’s approach the main emphasis is on the scientific process and the roles of the technological process and the social process are discussed only in general terms and in relation to the scientific process. In Nonaka’s approach, established for industrial and commercial organizations and based on technological knowledge within such organizations, the details of the structure of the social process are given without paying attention to the scientific process. To synthesize of the two approaches into a new model, it was necessary to identify possible associations between them. In particular, the negotiation of meaning and the creation of scientific and technological knowledge in the social process of Kurki-Suonio could be matched with the creation of tacit knowledge, mental models and technical skills in Nonaka’s socialization mode. Furthermore, the transformation from empirical meaning to conceptualization can be correlated with the process of articulating tacit knowledge into explicit knowledge. The hierarchical development of knowledge that distinguishes the scientific process in the perceptional learning approach is the process of systematizing concepts into a knowledge system typical of the organizational knowledge acquisition process. In other words, the increasing capacity of knowledge to create new knowledge corresponds to the reconfiguration of existing information, which leads to new knowledge. In addition, the empirical meaning is the starting point of knowledge and in Nonaka's theory this becomes to acquire tacit knowledge is experience. In addition, the relationship between theory and nature corresponds to the relationship between mental images and the creative process. This correlation yields the following question: how do experimental observations of nature and social processes and knowledge conversion interact to provide a complete picture of knowledge acquisition?

Using the theoretical approaches to find a possible answer to this question, this thesis proposes to show that manipulating nature, which drives the individual technological process and learning by doing, which characterizes the organizational social process, are fundamentally the same. This provides the opportunity to link the two approaches and create a new, more complete model of knowledge creation, acquisition and transfer. Observations and empirical investigations are sources of scientific knowledge creation and they represent the starting point of the learning process and the scientific concept formation process.

Starting from Figure 3.3 and Figure 3.4, representing the two spirals of both approaches, the author is able to construct similar illustrations in Figure 3.7 and Figure 3.8 respectively. Now, the spiral formed by the hierarchical structure of the conceptualization of science formed by the four levels of language, quantities, laws and theories can be combined with the spiral that takes place at the epistemological dimension across the four modes of knowledge conversion (internalization, socialization, combination and externalization).

Finally, the author proposes that the new model, which describes the knowledge creation path in the CERN context well, forms the learning process from an individual to knowledge acquisition in an organizational context and the acquired knowledge transfer from CERN to other institutions. In particular, organizational knowledge acquisition, now represented as a model in Figure 3.9, could also be interpreted as a description of the structure of the social process in the individual learning process, as is shown in Figure 3.10.

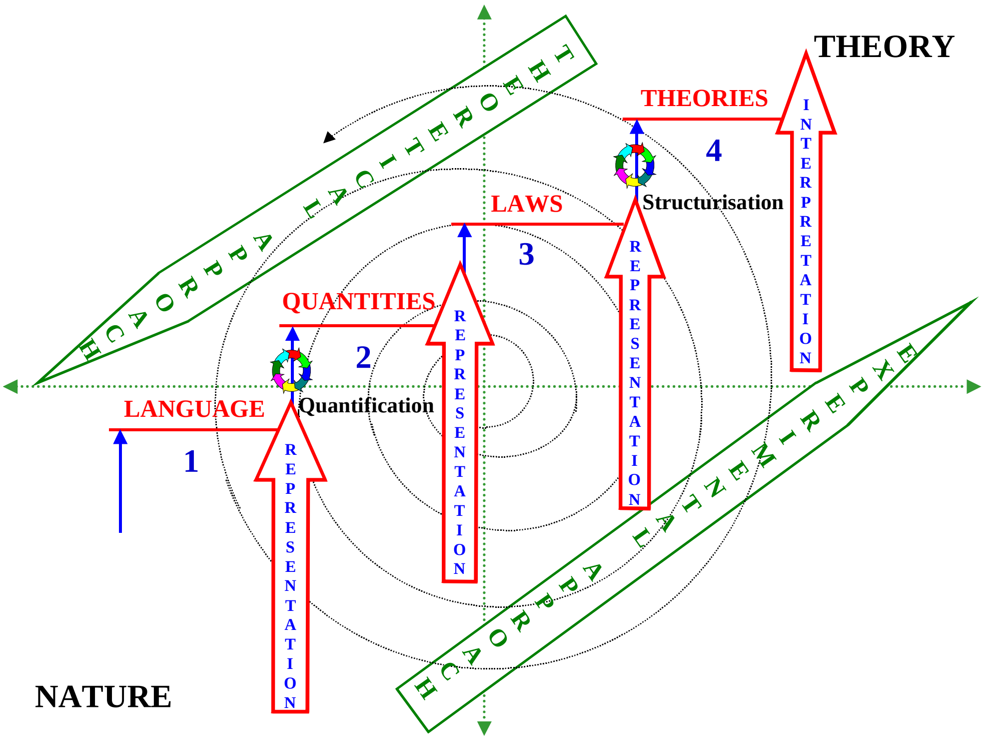


Fig. 3.7: Spiral in the unification process of the hierarchical structure of conceptualization.

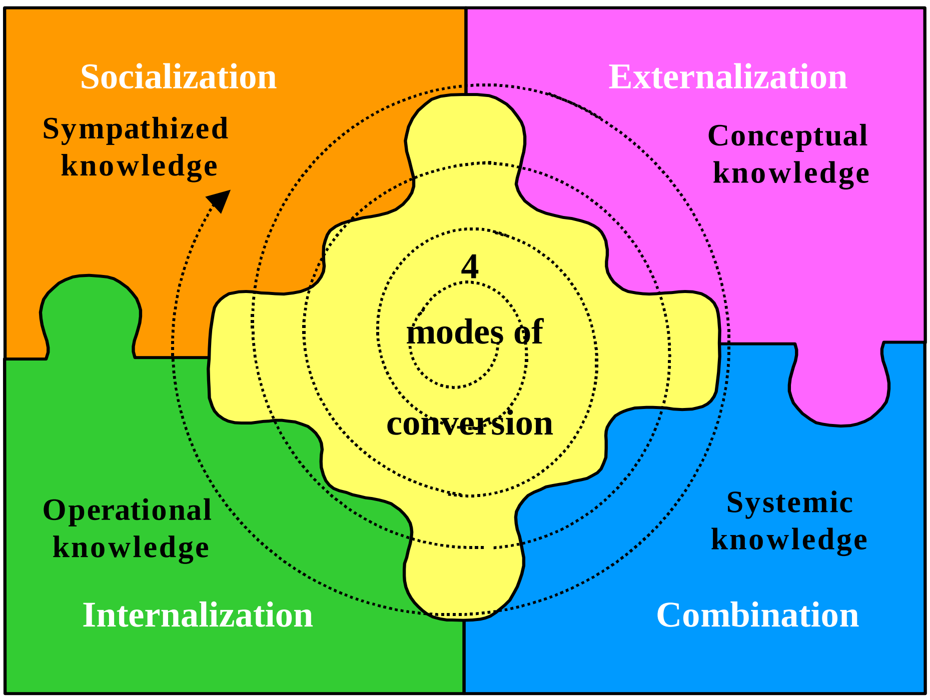


Fig. 3.8: The knowledge creation spiral at the epistemological dimension.

Figure 3.11 represents the new model combining the two different approaches. This representation shows the manner in which all three processes are represented. The final realization of the scientific and the technological processes are science and technology, which are manifested by methods and procedures and intertwined by the social process. The social process is to convert the tacit knowledge into external knowledge to realize the final step from individual learning to organizational acquisition.

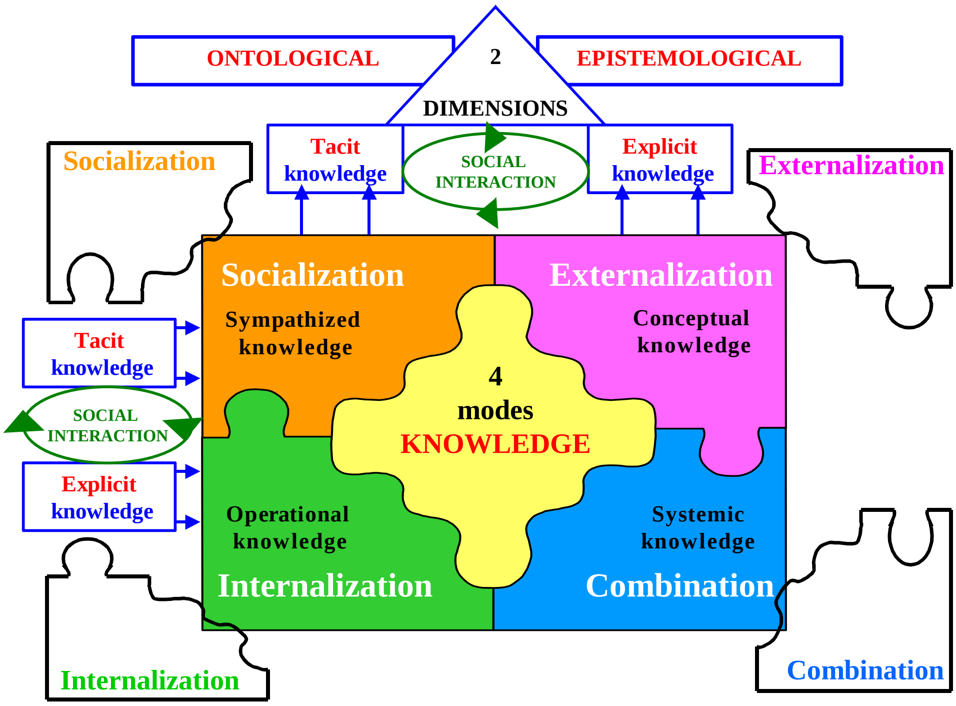


Fig. 3.9: Knowledge creation in an organization.

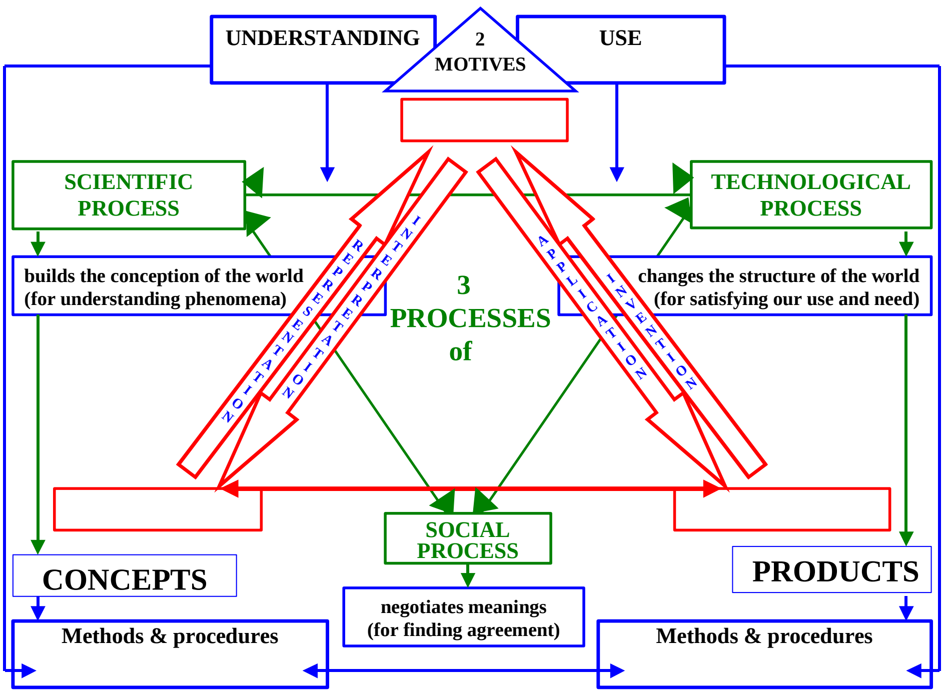


Fig. 3.10: Knowledge creation in the learning process.

In summary, this model takes into account the two different levels involved in creating, acquiring, and transferring knowledge: the individual and organizational learning. The characteristic of the first is the research spirit whereas for the second one it is the multi culture. The multicultural aspects represent both constraints and freedom. The constraints include the need for a mediating language to negotiate the meanings. The freedom creates an environment in which discoveries can be made. From this it can be derived that the best interaction between the individual and the organizational levels is represented by the balance between multicultural constraints and freedom typical of an international research organization such as CERN. Too much freedom involves a large financial implication and too many constraints result in lack of ideas and subsequently reduce innovation. In the Laboratory, the technology transfer is a possible balance between constraints and freedom as it represents the interaction between pure scientific research at an organizational level and daily technological application at an individual level. In Big Science centres the two types of individual and organizational knowledge creation are more closely correlated and interaction takes place as in conventional industrial environments.

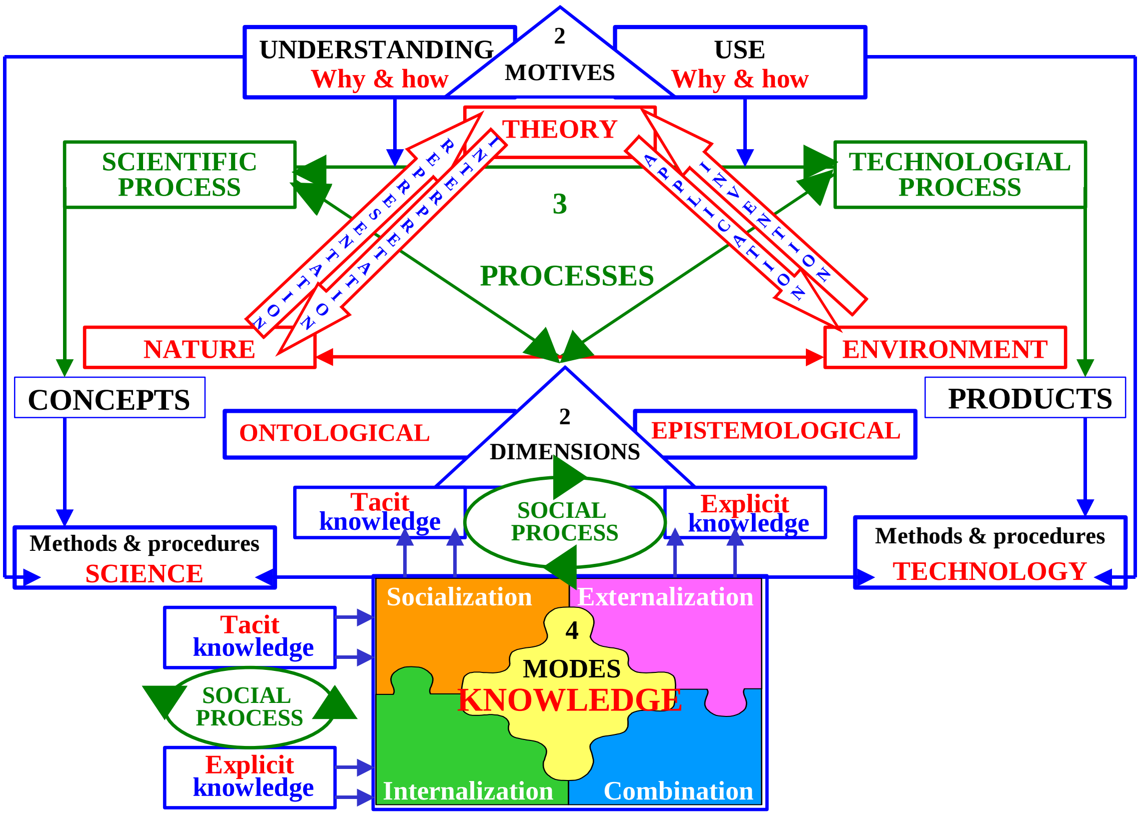


Fig. 3.11: Knowledge creation, acquisition and transfer in a research organization.

In order to facilitate interpretation and the conclusion of this work, it is important to notice that these both, the individual and the organizational levels, will always be present. Nevertheless, identification of either individual and organizational knowledge acquisition cannot always be clearly extracted from the results obtained by this research.

4. Research objectives and methodology

The present chapter is devoted to the research objectives and methodology of the study and describes the design of the questionnaire used for the investigation carried out in this thesis.

4.1 Research objectives

This research aims to test the ideas and propositions mentioned in the preceding chapters and to provide answers to two main questions. The first question and a related aspect are: what is the educational impact of an inter-governmentally funded scientific centre, CERN, for students and apprentices? What are the competitive core skills and acquired knowledge developed by people and what is the market value of these skills for Member States' industries?

The second question and a related aspect are: how does exposure of people to an international environment enhance their cultural and social dimensions? How does society benefit from this exposure?

The transfer of know-how by technology transfer through people, following employment at CERN was investigated in a sample of a several hundred Finns and Italians who participated in the CERN scientific programmes on a variety of contracts during the LEP period (1990–1999). In particular, the analysis is based on a sample comprising two categories of employees: Finnish employees across all CERN areas of work; and Italians who worked on the DELPHI experiment and in the EST division.

The sample consisted of 411 Finnish individuals selected via a search carried out on the CERN personnel database. The Italian sample includes a total of 106 individuals.[1] A questionnaire was developed to collect information on competitive core skills and knowledge acquired during work experience at CERN. The questionnaire was tested and used on the selected study sample.

[1] This sample was selected by direct contact with Tiziano Camporesi, the spokesperson of the DELPHI experiment and Cristoforo Benvenuti, the leader of the Surface and Material technologies (SM) group in the EST (Engineering Support and Technologies) division, as well as via contact with the former supervisors of the sampled individuals.

4.2 Procedure and methodology chosen

This study of CERN knowledge creation, acquisition and transfer consists of: introducing TT at CERN as the framework of the study (Chapter 2), constructing the model for analysis (Chapter 3), and preparing a web-based questionnaire for data collection and analysing the data according to the constructed model (Chapter 4).

For the Finnish sample, a specific FileMaker database, consisting of the records of all the sample of Finnish people, was created using FileMaker programme version 4.0 and analysed before sending the Web-based questionnaire. Fig. 4.1 shows a typical record form from the Finns FileMaker database. About half of the sampled individuals were still registered at CERN, i.e. they could in principle easily be contacted via their CERN e-mail accounts. The CERN human resources database provided the information for only about 50% of these records, classified according to the type of contract with which the person is registered at CERN, and containing historical information. Then, it was necessary to consult the CERN archives. As much of the available information in the CERN archive was collected on the 411 Finns as possible. Once the data of the sample were properly organized in the database, a first statistical analysis on the Finnish sample was made (Section 5.1).

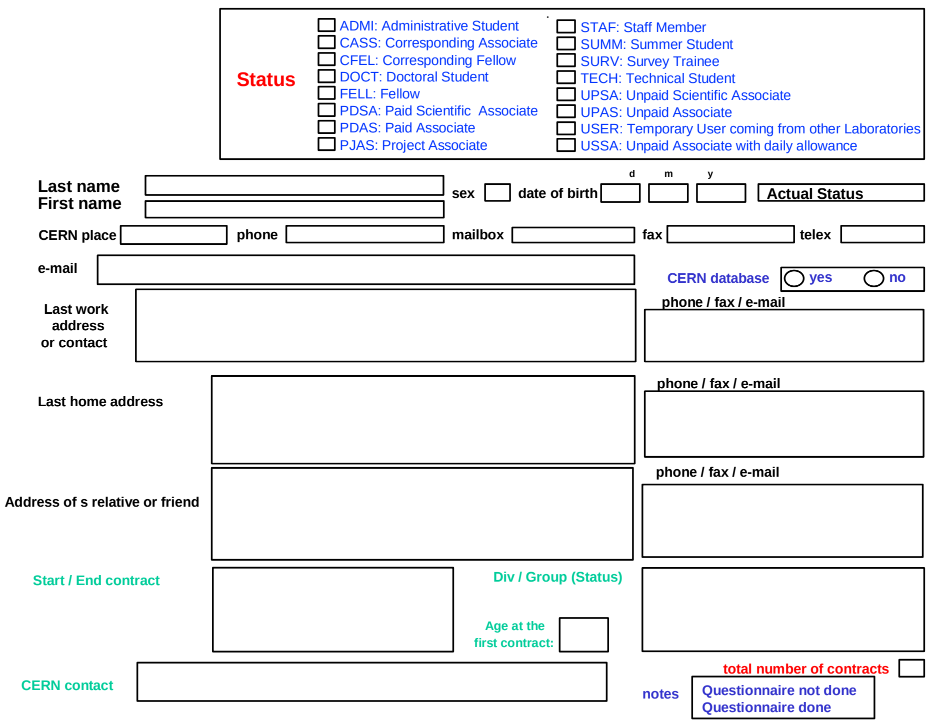


Fig. 4.1: Record form from the Finns FileMaker database.

A Web-based questionnaire linked to a new FileMaker database (see Section 4.3) was sent to all the Italians and the Finns.[2] Apart from the basic questions concerning educational background, status when at CERN and current professional situation, a series of questions relating to professional specialization and the technologies used or developed during each person's stay at CERN was asked. To cover the sociological aspects of this study, a series of questions was also asked regarding the professional and human experience acquired by the person during their stay at CERN. In order to understand the knowledge acquisition process a key element of the information was requested what the person considered as being his/her most important scientific publications. It required some collaboration from supervisors to encourage people, especially on the Finnish side, to fill in the Web-based questionnaire.

The results of the Web-based questionnaire improved information on fields of expertise available on the existent Finns FileMaker database to make available to industry a list of experts for domains of activities.

In order to validate the content of the Web-based questionnaire, a pilot study was carried out (Section 4.3.2). A detailed analysis of the answers was used to finalize the questionnaire and make statistical analysis easier. Where Internet access was not available, the questionnaire was sent via normal mail a covering letter (Appendix C). In some cases replies were also obtained by direct contact (by the phone or personally, where it was possible) the people that could be reached.

The procedures used with the Finns and Italians were different. As previously illustrated, in the case of the Finns, an archival search was carried out, which demanded more time to classify all the data. In the case of the Italians, the supervisors and the group leaders of the people involved were contacted to obtain the necessary information which took less time. These differences are because, the Finns come to CERN and then return home, while the Italians return to Italy but return to CERN more often to use the Laboratory's facilities. It was easier therefore to obtain information from the Italians than from the Finns, because the Italians were in closer proximity, more often at CERN and the author was able to contact them personally.

Some questions in the questionnaire proved difficult to interpret in the absence of an interviewer and this reduced number of the responses by Web or mail. The

[2] http://itlopc03.cern.ch/PhDFinland/questionnaire.html.

Finnish sample responded at the rate of 11.44%, while 48.11% of the Italian sample responded. Responses to the questionnaire from those working in a technological or industrial, rather than an academic environment, were more immediate. This is because the private sector is aware of the importance of technological spin-offs, as spin-offs are among of their main aims, and this is not the case in pure research. Keeping the above considerations in mind, what follows is very much a case study. This will not, however, have a major influence on drawing the conclusions from data.

4.3 Questionnaire design

The questionnaire (see Appendix D) was structured to determine what the respondents have learnt from their experience at CERN in terms of acquired knowledge and know-how and how this has been transferred to their subsequent professional post. Some questions look similar, but are in fact a cross control to find out whether the respondent gave contradictory answers or had a true perception of their acquired knowledge.

4.3.1 Structure

The first part of the questionnaire is dedicated to personal information, asking for a description of the current position held by the respondents, as well as the position held while at CERN. With reference to the positions held at CERN, the questionnaire requires information on: field of activity at CERN; affiliation (if different from CERN); location while at CERN such as Division, Experiment and/or Group; name and responsibility of direct supervisor; and date and status of the contract(s) for all positions held at CERN.

The respondents were required to summarize the studies undertaken in the scientific domain: computing, electronics, mechanics, material science, acceleration techniques and others. These domains are subdivided into three possible stages: test, analysis and development. It also asks for a list of the main publications produced during the periods while at CERN.

The second part comprises 21 questions (Fig. 4.2), of which nine require quantitative assessment, namely either a number ranging from 1 to 5, Yes / No answer with reasons, or a tick in the relevant box.

The 12 remaining questions are of the open type and require respondents to elaborate their answers. The first four questions (1–4) concern acquired knowledge, skills and topics and are intended to be the core questions. The first question invites the respondent to quantify his/her most important scientific and technical contribution while at CERN, (labelled 1–5 in order of importance, 5 being most important) within the domains of physics, engineering and finance and administration. In the second question, the respondent has to illustrate his/her acquired knowledge in the above-mentioned sub-domains, outlining possible technological innovations resulting from this acquired knowledge. The third question comprises a list of categories (theoretical physics, experimental physics, computing, technical fields, financial aspects, languages, communications, science communication and organizational/managerial aspects) in which respondent is asked to specify his/her acquired skills. The fourth question aims at evaluating the impact of interaction with both CERN colleagues and external colleagues, and if and how this interaction contributed to the acquisition of knowledge while at CERN.

The impact of working in the CERN international and multicultural environment is analysed in questions 5, 6, 7 and 11. Questions 14, 15 and 20 relate to the transfer of personal professional skills acquired at CERN to subsequent professional experience. Two questions (8 and 9) are dedicated to the impact of CERN training, lectures and seminars on the acquisition of knowledge. Questions 10, 12, and 13 refer to respondents' expectations of CERN and their fulfilment. Respondents were invited to make suggestions for improvements. Question 16 relates to participation in R&D projects and 17 to the description of the possible return or application of acquired technologies, and both questions aim to assess the respondent's awareness of the notion of technology transfer and his/her opinion of R&D activities. In question 18, the respondent is invited to evaluate the impact on learning of meetings held at CERN. The meetings are divided into four categories: general meetings, collaboration meetings, divisional or group meetings and project meetings. These are then evaluated with respect to: illustration of subjects, definition of problems, work organisation, management and time schedule. Question 19 requires a quantitative assessment. It compares the CERN experience with the subsequent work experience with respect to managerial aspects, scientific stimulation, financial considerations and multicultural aspects. Question 21 is of sociological interest and aims to determine whether the stay at CERN modified any cultural habit or facilitated cross-cultural know-how acquisition. The open section, allowing comments and adaptation to respondent's personal cases, completes the questionnaire.

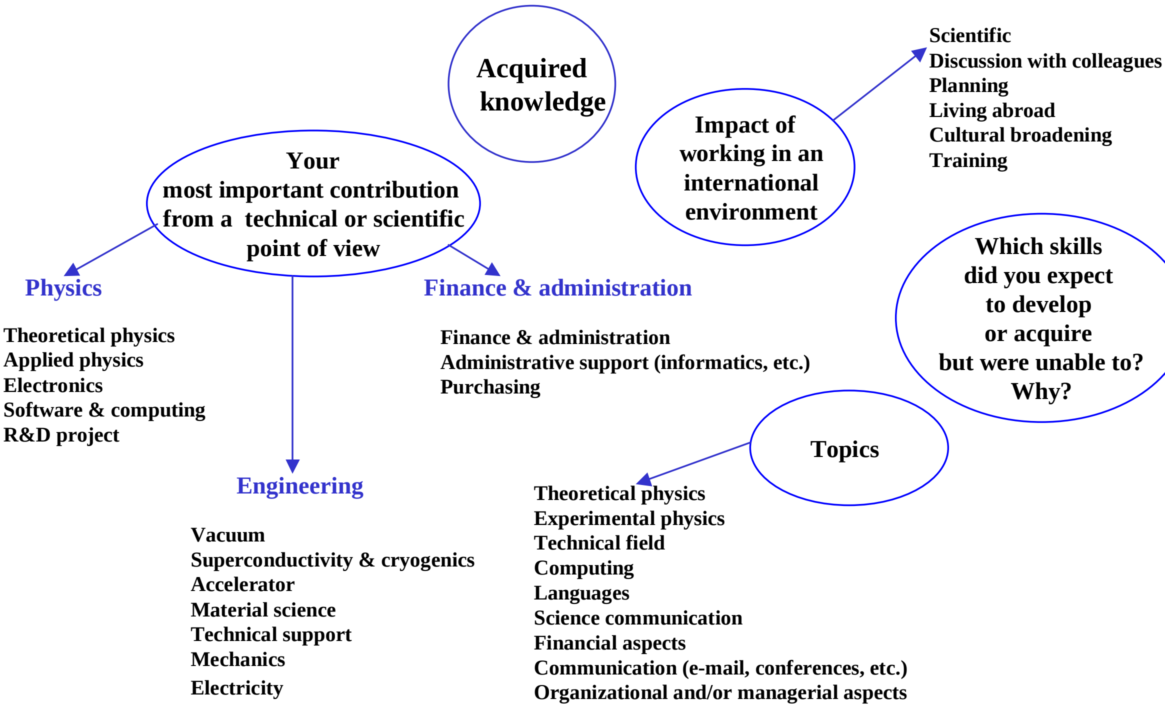


Fig. 4.2: Outline of the online questionnaire.

4.3.2 Pilot study

The pilot study, which consisted of completing the questionnaire by individual interview, was carried out to verify the questionnaire's clarity (e.g. terminology or interpretability of questions). The replies and comments made in the pilot study were used to improve and finalize the questionnaire. This pilot study was also used to assess the amount of time necessary to complete the questionnaire. Respondents were requested to answer the questions in full, accurately and in as much detail as possible.

Ten people, neither Finnish nor Italian, holding different positions (engineer, physicist, technical student, computer scientist and high school science teacher) and therefore representative of the sample population, were chosen according to their age and experience or relationship with CERN (Fig. 4.3). Among the four physicists and two computer scientists, two CERN senior staff members were included, their fields of activity being in biomedical applications of high energy physics (HEP) technologies, in detector design and in calibration and control systems. The computer scientists worked in the field of distributed systems, object-oriented database management systems and component software technology. Both the fields of bio-medical applications and of software computing are domains at CERN with a large potential for technology transfer.

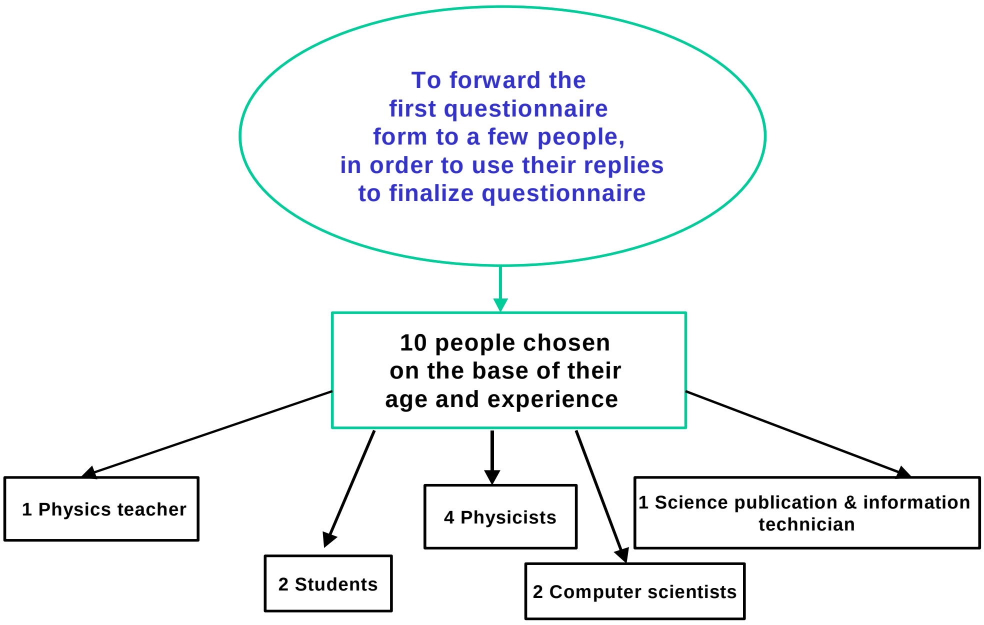


Fig. 4.3: Pilot study.

Input from people working in the technology transfer field was fundamental to assess aspects related to technology transfer and the awareness of impact of technology transfer and the contribution derived from CERN activities. The physics teacher was a CERN Unpaid Associate. Those with permanent staff positions at CERN, due to their age and experience, tend to deal with support groups and with the management of large projects. The person interviewed with a temporary position at CERN works in large international teams, and has the opportunity to develop language skills, to promote innovative education tools and to spread knowledge from HEP to other fields.

The impact of working in an international environment was found to be important with respect to discussion with colleagues, living abroad, aspects of cultural broadening, scientific points of view, training and planning. The impact of training and seminars at CERN were important for both personal interest and skill acquisition. Teamwork was another skill learned, improving personal capacities and ability. As one of those who completed the pilot study questionnaire stated: "My fundamental education has impregnated me with the highest consideration for human relations; therefore I enjoy the contacts with colleagues coming from other cultures which allow me to kill the a priori platitudes of my education and enrich my personality".

With reference to experiences at CERN, what emerge from the pilot study as important positive aspects are the multicultural opportunities, learning, and scientific contacts. The main criticisms concerned management, resources, time pressure and lack of communication. Management was confused and resources reported to be badly distributed. Regarding lack of communication, this was especially related to the absence of communication in working towards the common goals between Sectors, Divisions in the same sector, and Groups in the same Division. One respondent suggested increasing contacts and discussion on the day-to-day issues, first in the Directorate, and then between Directors and Division Leaders, in order to avoid the creation of individual 'kingdoms'. The parameters analysed to assess the positive and negative aspects of the CERN experience perceived by the pilot study sample are reported in Fig. 4.4.

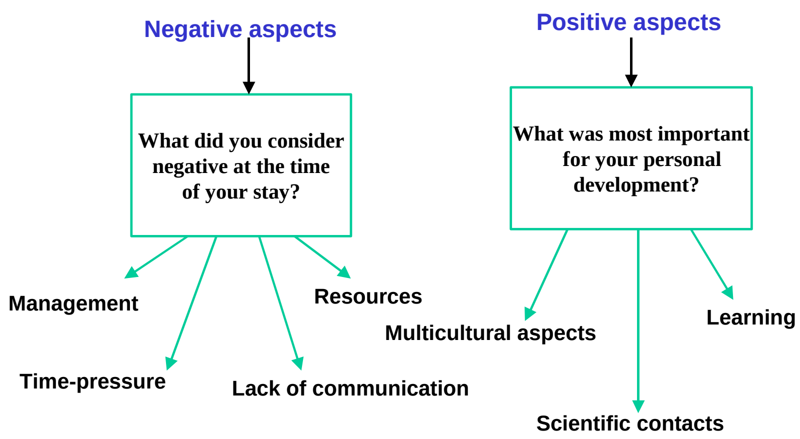


Fig. 4.4: Positive and negative aspects of CERN perceived by the pilot study sample.

The pilot study allowed the author to eliminate the overlap between questions, thereby ensuring the questions were well defined and covered the domain of the investigation. The results of the pilot study did not however necessitate substantial modification of the questionnaire, since respondents' comments were mainly language-based (for example, one interviewee suggested the use of more adjectives in the formulation of questions).

An average of 40 minutes was recorded for completing of the questionnaire.

4.3.3 Online questionnaire and link to FileMaker database

The questionnaire was written in HyperText Markup Language (HTML) in order to allow the respondents to access it and to respond via their Web browsers. Then the Web version of the questionnaire was linked to the FileMaker database created using FileMaker programme version 4.0. The link between the online questionnaire and the FileMaker database was essential for data analysis, once the information has been inserted. A detailed description of how the FileMaker database was created and linked to the Web-based questionnaire is provided in Appendix E.

4.3.4 Relationship of the questionnaire with the model of knowledge creation, acquisition, and transfer in a research organization

To be able to make use of the model as a theoretical framework for the analysis of the factors in knowledge acquisition affecting technology transfer (TT) it is necessary to discuss in more detail the relationship of the questionnaire to the CERN knowledge creation, acquisition and transfer model developed in Chapter 3.

As a research centre at the forefront of science, CERN is an active agent in the process of advancement of science and technology. The individuals in this study's sample are participating in this process while undergoing their own individual process of learning. They have, thus, a relation to the scientific process (SP), the technological process (TP) and the social process (SoP) of both the process of advancement of science and technology and the individual learning process. TT is one special example of the SoP in the advancement of science and technology.[3] Knowledge created in the advancement of science and technology is the source of the technology to be transferred, but TT also requires the process of each individual. The association of knowledge acquisition with TT is just one special manifestation of the inseparable intertwining of the three processes.

The questionnaire deals with different aspects of knowledge acquisition from the point of view of the individuals of the samples: the kind of knowledge and skills acquired by the individuals, the individuals' participation in the advancement of science and technology while at CERN and their possible active role in TT afterwards, and a personal evaluation of the importance or usefulness of different CERN activities for the acquisition of different kinds of knowledge and skills. Questions (and answers) related to any of these aspects of the questionnaire are associated with the SP, TP or SoP in that they refer to knowledge or skills characteristic of the aims, products and procedures of the three processes.

The SP is a mental process, which aims at conceptual understanding. Concepts and conceptual structures representing natural phenomena are therefore results of the SP. Procedures, both experimental and theoretical, used in the creation of concepts are procedures of the SP. The TP is a practical process of manipulating nature. Any useful products, applications, innovations, or solutions of practical problems, including the design of scientific experiments are results of the TP. The SoP aims at establishing agreement about scientific and technological aims, results and procedures through interaction between people and groups. Communication, negotiation, reporting, teaching, learning, etc. belong to the SoP's procedures. Languages and language, in the broad sense, are tools of the SoP.

As a consequence of the strongly hierarchical nature of knowledge and skills in the SP and TP, people participating in the SoP represent different hierarchical levels of competence, depending on the level they have reached in their separate individual processes. The nature of the different procedures of the SoP such as

[3] Technology transfer of could also be interpreted as diffusion of innovation. One of the diffusion models is Rogers general model of diffusion of innovations in which there are similarities between different kinds of innovation and social systems. A universality or similarity found among the various research studies on the diffusion of innovation process is the adoption process or the rate of diffusion by individuals of the social system. Rogers emphasizes the importance of the interpersonal diffusion network, which influences individuals' adoption process. He also emphasizes that communication through different channels, or a process in which participants create and share information with one another in order to reach a mutual understanding is essential to the diffusion of the innovation [Rog95].

teaching, learning, training, discussion or participation in meetings, lectures, seminars, etc. therefore varies from the point of view of an individual, depending on his or her competences and those of others. On this basis the connections of the questions with the underlying model of the study can be discussed in more detail.

Question 1 (**Q_1**) asks for an assessment of the respondent's "most important contributions from a technical or scientific point of view in order of importance". This general formulation refers to participation in knowledge acquisition in the advancement of science and technology as part of either the SP or TP, without specifying the nature of the contribution (which can be interpreted to include both results and procedures, i.e. conceptual or practical knowledge and know-how).

Respondents are asked to categorise their replies according to lists of domains divided under three headings. The first two, physics and engineering, correspond roughly to the SP and TP respectively. All fields given under both headings represent both processes, except for theoretical physics, whose concentration on conceptual understanding means it falls under the SP. However, as the headings represent separate processes it reasonable to expect that the fields under each heading will emphasize achievements belonging to the areas of the SP and TP respectively.

The third heading, Administration, extends the scope of the question to achievements belonging to the SoP.

Questions 2 and **3** (**Q_2**, **Q_3**) ask the respondents to describe their acquired knowledge in general and according to topic referring to their individual processes. The general formulation of the question covers knowledge related to all or any of the three process elements. The nine fields listed in the second part of question 3 have a more specific relation to the processes. Theoretical physics belongs to the realm of the SP, as do experimental physics and computing, where the TP also has a role in arranging of experiments and in computing technology. Technical fields are dominated by the TP. The rest, financial aspects, languages, communication, science communication and organizational and/or managerial aspects refer more or less directly to different aspects of the SoP.

Question 4 (**Q_4**) asking for "fields of interest developed or topics studied by interacting with colleagues at CERN or outside CERN" refers to the effect of the SoP on knowledge acquisition. The nature of 'fields' or 'topics' is not specified, but they should be understood to be in the domain of either the SP or TP (although SoP is not explicitly excluded (like **Q_1**).

Questions 5 and **6** (**Q_5, Q_6**) ask respondents to select which fields or topics listed in **Q_4** have been "put into practice" after leaving CERN and which "has proved the most useful". "Putting into practice" refers to the use of knowledge acquired in scientific or technological research and is, thus, related to the quality of the individual SP or TP, depending on the nature of the knowledge. It also allows direct reference to TT. In the light of **Q_4**, the replies reflect the quality of the SoP as the activator of the SP and TP.

Questions 7, **8** and **9** (**Q_7, Q_8** and **Q_9**) ask about the fruitfulness of different CERN activities and the aspects of the stay at CERN. The general formulation of **Q_7**, "the impact of working in an international environment", refers to the interaction of individuals with their environment and the effect of the international atmosphere, which is an important dimension of SoP at CERN.

'Discussion with colleagues' can be regarded as the main procedure of the SoP, supporting any of the sub-processes in the advancement of science and technology and in the individuals. 'Colleagues' indicate that in the SoP participants are supposed to be roughly equal in competence. 'Living abroad' and 'cultural broadening aspects' have a loose general connection with the SoP of the individual. 'The scientific point of view' refers formally to the SP of the individual, but in view of the generally wide understanding of the word science TP may also be included. 'Training' is a SoP procedure involving trainees and trainers representing two different levels of competence. The respondent is assumed to be a trainees and the training would support either the SP or TP or both. 'Planning' refers to a SoP procedure aimed at either the advancement of science and technology at CERN or the individual process of the respondent. Participants may be of different levels of competence.

Question 8 (**Q_8**) asks about the "impact of training" in general, without emphasis on any specific aspect. This question involves one type of SoP: the interaction between trainer and trainee. The difference between the four specific fields of **Q_8** is due to the different hierarchical levels of the participants and the position of the respondent in the training. In 'CERN Education Service Training' the respondent could play an active role. This may be the case also in 'summer student lectures', 'academic training' and 'seminars', but essentially the respondent holds the position of trainee. The hierarchical distance between trainer and trainees is presumably different in all four cases.

Question 9 (**Q_9**) asks about the most impressive “lectures”, attended both “for skill acquisition” and “for general interest”. Lecture is understood as a well-defined type of SoP training, where the respondent is in the position of a trainee. It can have a direct effect on the individual SP of the trainees. This effect is characterised particularly by general interest. The first specification, skill acquisition, invites more long-term effects, which can also be in the domain of the TP.

Question 10 (**Q_{10}**) asks for “skills not developed despite one’s expectations”. This, with **Question 12** (**Q_{12}**) and **Question 13** (**Q_{13}**) invites criticism of knowledge acquisition at CERN. No suggestions are made regarding any specific CERN procedures for addressing the criticism, but four fields are given to specify the nature of the dissatisfaction. ‘Education’, ‘management’ and ‘communication’ skills are all abilities to apply certain kinds of the SoP procedures. Education refers to procedures used for advancement of the students’ individual processes, predominantly the SP, while in management and communication the aims of the procedures are primarily part of SoP. ‘Technical skill’ refers simply to the TP procedures.

Question 11 (**Q_{11}**) asks whether the “multicultural aspects of CERN has had an influence on one’s career development” and why. This again refers to one characteristic of the SoP as a possible agent affecting one’s individual process, which may include participation in the advancement of science and technology. The question investigates the connection of the replies with all process elements. **Question 12** (**Q_{12}**) “fields or subjects (which did not meet one’s expectations)” can be connected equally to the SP and TP.

Questions 13, **14** and **15** (**Q_{13}**, **Q_{14}** and **Q_{15}**) are very general in nature, asking what the respondent “considered negative (in CERN)”; “what (aspect in CERN) was most important for one’s personal development”; and **“**which technology acquired or skill improved while at CERN has had the greatest impact on one’s career”. **Q_{13}** and **Q_{14}** can be associated with any process elements. ‘Technology acquired’ refers to the TP but the ‘skill improved’ as well as the ‘impact on one’s career’ may belong to any of the processes.

Question 16 (**Q_{16}**), “participation in R&D projects”, is directly related to the SoP: its role is to support the SP and TP of the advancement of science and technology.

Question 17 (**Q_{17}**) concerning possible “technological return or application” is in the realm of the TP and implies some TT.

Question 18 (**Q_{18}**) asks about "positive or negative experience of four types of meetings", regarding five different aspects of the fields discussed. The types of meetings, 'general', 'collaboration', 'divisional or group', and 'project meetings', represent different organized modes of the SoP procedures in CERN, involving interaction of individuals of different hierarchical levels in the domains of the three process elements. The five aspects are related to the aims of the meetings regarding both the advancement of science and technology at CERN and the individual process of the participants. Two aspects, 'illustration of subjects' and 'definition of problems', as discussed in the meetings, belong dominantly to the domain of the SP, although the subjects and problems discussed can equally be related to the TP procedures, while 'work organization', 'management' and 'time schedule' refer mainly to different SoP procedures.

Question 19 (**Q_{19}**) calls for a "comparison of work experience and CERN experience from the point of view of the learning process". Specific fields are covered: 'managerial' and 'financial considerations' refer to knowledge and skills related to certain types of SoP procedures, 'scientific stimulation' refers directly to SP and TP, while 'multicultural aspects' is related somewhat loosely to quality questions of SoP (like **Q_{11}**).

Question 20 (**Q_{20}**), like **Q_{15}**, pays attention to the possible influence of working at CERN on one's career. Asking simply whether the respondent has "obtained a position thanks to the experience acquired at CERN" has no link to any of the process elements of science and technology or learning.

Question 21 asks about possible "influence of the stay at CERN on cultural interests outside one's country of origin", specifically as regards 'holidays', 'language', 'food habits', 'sport' and 'hobbies'. The general formulation and the specific fields mentioned are related to certain quality aspects of the SoP.

Table 4.1 presents a summary of the relations of the questions in the questionnaire to the structure of the CERN knowledge creation, acquisition and transfer model developed in Chapter 3.

Table 4.1: Connection of the questions to the knowledge creation, acquisition and transfer model.

Question		**General formulation**	**Fields in the formulation**	**Scientific process (SP)** **Technological process (TP)** **Social process (SoP)**
N°	**Type**			
Q_1	Quantitative assessment, labelled in order of importance (1-5 = max.)	Your most important contribution from a technical or scientific point of view	1) Physics: Research, theoretical physics, applied physics, electronics, software & computing, R&D projects 2) Engineering: vacuum, superconductivity & cryogenics, accelerator, material science, technical support, mechanics, electronics 3) Administration: administrative support, purchasing, finance & administration	The general formulation refers to SP and TP The fields 1), 2) and 3) represent SP, TP and SoP respectively The detailed itemization of the fields 1) and 2) contains elements that belong simultaneously to SP and ST and all the items of field 3) are part of SoP
Q_2	Open	Acquired knowledge		The general formulation refers to the connections between SP, TP and SoP
Q_3	Quantitative assessment, ticked in the relevant boxes	Acquired knowledge per topic	1) Theoretical physics 2) Experimental physics 3) Computing 4) Technical fields 5) Financial aspects 6) Languages 7) Communication 8) Science communication 9) Organizational and/or managerial aspects	The general formulation refers to the connections between SP, TP and SoP Fields 1) and 2) belong to SP, but field 2) contains technological components belonging to TP Fields 3) and 4) are directly connected to TP. The fields 5), 6), 7), 8) and 9) belong to the SoP area
Q_4	Open	List the fields of interest developed or topics studied by interacting with colleagues at CERN or outside CERN		This question, together with Q_5 and Q_6, belongs to SoP In particular: in the general formulation, 'field of interests' and 'topics studied' are directly connected with SP and TP and 'interacting with colleagues' is linked to SoP
Q_5	Open	Which one of the answers to Q_4 have you put into practice after your stay at CERN?		See question Q_4
Q_6	Open	Which one of the answers to Q_5 has proved the most useful?		See question Q_4
Q_7	Quantitative assessment, tick the relevant boxes	Impact of working in an international environment	1) Discussion with colleagues 2) Living abroad 3) Scientific point of view 4) Cultural broadening aspects 5) Training 6) Planning	This question refers to interaction of the individuals with the entire environment Fields 1), 2), 4), 5) and 6) refer to SoP involving elements of SP and TP; while field 3) has direct connections with SP
Q_8	Quantitative assessment, tick the relevant boxes	Impact of training	1) Summer student lectures 2) Seminars 3) Academic Training 4) CERN Education Service training	This question involves one type of SoP: the interaction between trainer and trainee The fields refer to SP and TP in the SoP, between hierarchical levels
Q_9	Open	Which lectures have impressed you most?	For skill acquisition For general interest	See question Q_8

Table 4.1 continued

Question		General formulation	Fields in the formulation	Scientific process (SP) Technological process (TP) Social process (SoP)
Nº	Type			
Q_{10}	Open	Which skills did you expect to develop or acquire but were unable to?	1) Education 2) Management 3) Communication 4) Technical skill	The criticism of knowledge acquisition invited by this question and by Q_{12} and Q_{13}, refers to the roles of: SP in field 1);TP in field 4); and SoP in fields 1), 2) and 3)
Q_{11}	Open	Have the multicultural aspects of CERN influenced your career development?	Yes, why? No, why?	The general formulation of this question refers to SoP
Q_{12}	Open	Which fields or subjects did not meet your expectations?		In the general formulation, words 'fields' and 'subjects' are directly connected with SP and TP. See referring to Q_{10}
Q_{13}	Open	What did you consider negative?		See Q_{10}.
Q_{14}	Open	What was the most important for your personal development?		The general formulation is related to all three processes SP, TP and SoP
Q_{15}	Open	Which technology acquired or skill improved while at CERN has had the greatest impact on your career?		The general formulation is related to TP, but does not exclude scientific and social skills, which are features of SP and SoP respectively
Q_{16}	Quantitative assessment, Yes or No button ticked	Participation in R&D projects		Participation in projects belongs to SoP The general formulation involves also SP and TP
Q_{17}	Quantitative assessment, Yes or No button ticked	Are you aware of any technological return or application?	If yes, what was that? In which area?	The general formulation refers to TP
Q_{18}	Quantitative assessment, Yes or No button ticked	Positive or negative experience of meetings	General, collaboration, divisional or group and project meetings, all valued regarding: 1) Illustration of subjects 2) Definition of problems 3) Work organisation 4) Management 5) Time-schedule	The general formulation is related to SoP Sub-fields 1) and 2) are connected to SP and TP; whereas fields 3), 4) and 5) to SoP The different types of meetings refer to SoP in interaction of the individual with different hierarchical levels
Q_{19}	Quantitative assessment, labelled in order of importance (1-5, = max.)	Outline the difference between actual work experience and CERN experience according to the learning process acquisition	1) Managerial 2) Scientific stimulation 3) Financial considerations 4) Multicultural aspects	The general formulation contains certain kinds of SoP. Fields 1) and 3) belong to SoP and contain elements of SP and TP Field 2) refers to SP involving technological components, which are features of TP Field 4) is connected to SoP.
Q_{20}	Open	Have you obtained a position thanks to the experience acquired at CERN?		This question does not contain any particular elements of any of the three processes SP, TP or SoP
Q_{21}	Quantitative assessment, Yes or No button ticked	Had your stay at CERN an influence on cultural interests outside your country of origin?	1) Holidays 2) Language 3) Food habits 4) Sport and hobbies	The general formulation and all the fields can be used for social analysis, which represents SoP

4.4 Data collection procedures

The procedure described below was used to obtain the samples after the preliminary email was sent to the Finnish sample on 7 September 2000 to which nine answers were received. On 15 September letters were sent to those without email addresses to which four answers were received. After this, reminders were sent out via the Web with the following results:

- The first reminder was sent after one month and a half, on 26 October 2000. Twenty-one answers were received.
- The second reminder was sent after another month, on 26 November 2000. Six answers were received.
- The final reminder was delivered by interviewing the sample persons via telephone or meeting them personally, starting from 1 January 2001. Seven answers were received.

In total 47 questionnaires were received from Finns by 31 March 2001 (Fig. 4.5).

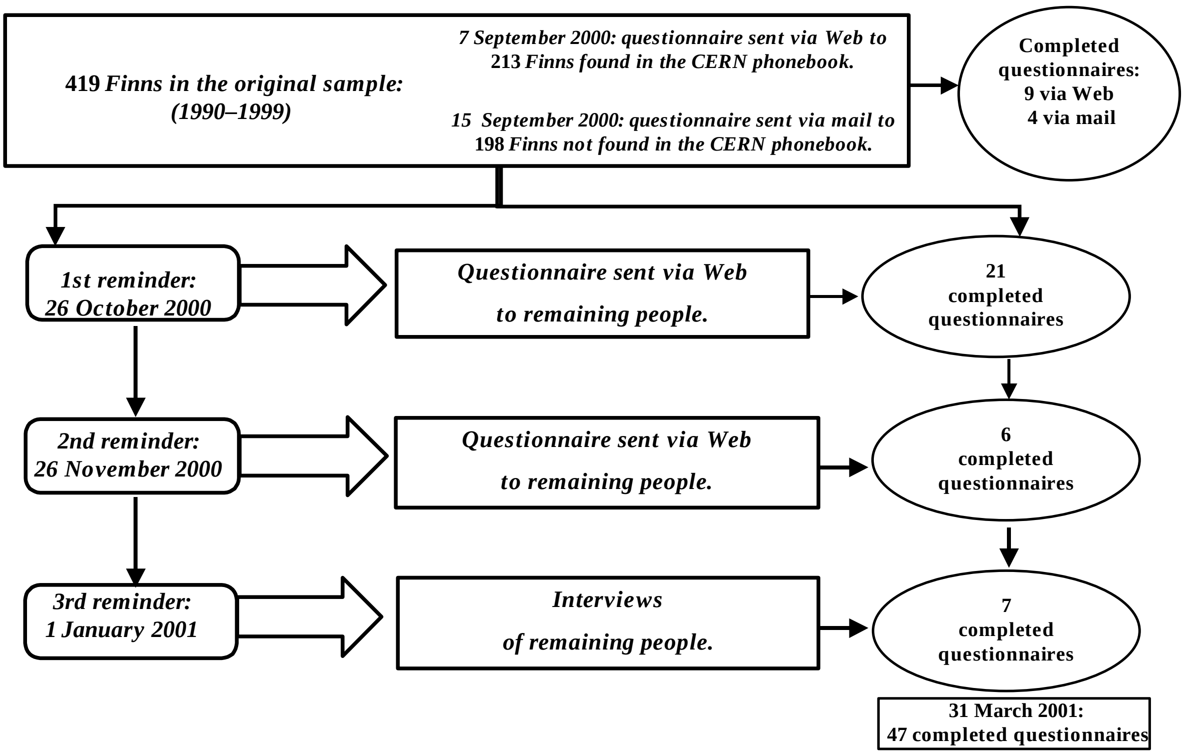


Fig. 4.5: Data collection for Finnish sample.

For the Italians the first email was sent on 25 March 2001 and 16 answers were received. On the same day letters were sent to those without email address from which one answer was received. After this, reminders were sent out via the Web with the following results:

- The first reminder was sent after a month on 25 April 2001.
  Ten answers were received.
- The second reminder was sent one month later on 25 August 2001.
  Eight answers were received.
- The final reminder was delivered by interview via telephone or via personal meeting, starting from 15 September 2001.
  Sixteen answers were received.

In total 51 answers were received from Italians by 31 December 2001 (Fig. 4.6).

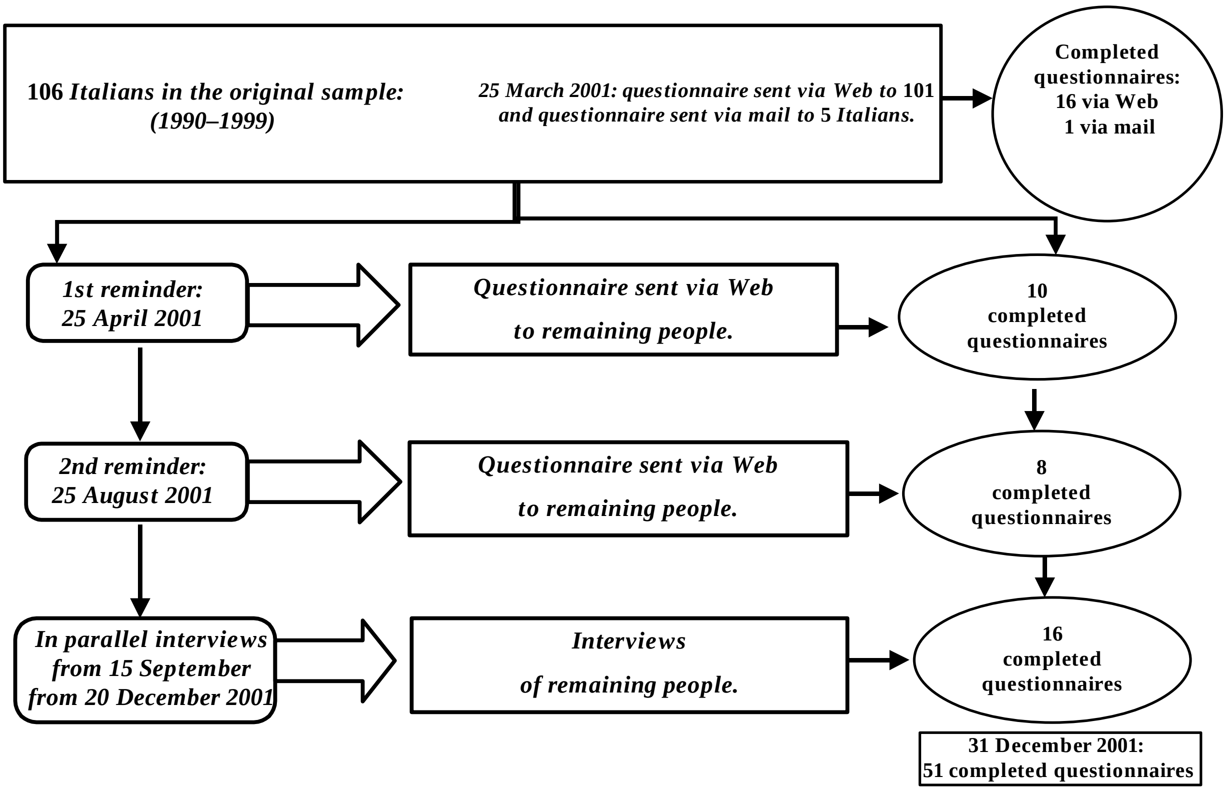


Fig. 4.6: Data collection for Italian sample.

4.4.1 Adjustments needed while collecting data

Figure 4.7 shows the first hypothetical plan for data collection. The first idea was to divide the procedure into three steps: first, to create a general questionnaire to be sent to each person in the sample. This questionnaire covered the following areas: skills, competencies, education impact and career. The second step envisaged the formulation of a specific questionnaire for the supervisor or group leader of a selected number of people from the first sample. The second questionnaire covered skill development and the educational impact of the CERN experience. The third step involved interviews with a farther sample selected from those of the first two questionnaires, covering the following criteria: technology transfer impact and career impact.

This research procedure was foreseen for both the Finnish and Italian samples. However, having started with the Finnish sample, the author realized that the data and collection were not completely satisfactory. The first obstacle was encountered after sending the first questionnaire to the Finns, as response time was very long. Therefore, the author decided to use just one questionnaire and to send out reminders. It also proved efficient to contact supervisors and group leaders. This was the reason for the different selection criteria in the second sample, the Italian one. Results differed which highlighted this difference in selection criteria.

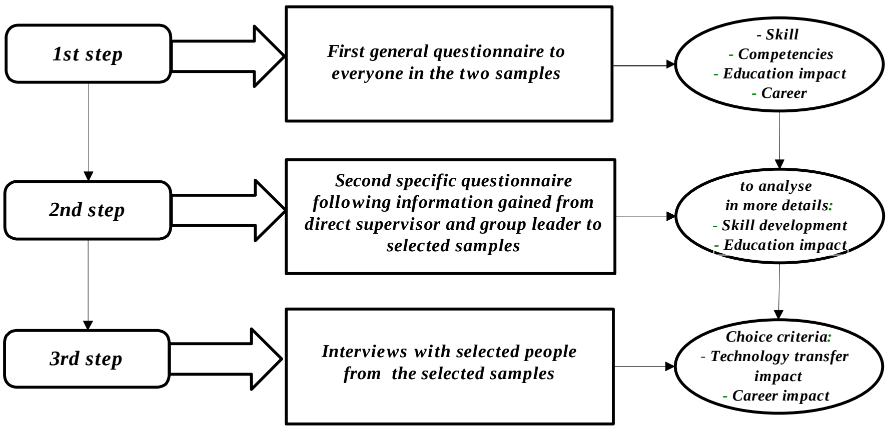


Fig. 4.7: First data collection plan.

The choice to hold personal interviews came later, as data from the replies received electronically or by post were insufficient. The interviews were more beneficial as the author obtained the data immediately.

Throughout the field study the author played the role of an observer, and it is necessary to clarify some difficulties resulting from what is called ‘the observer’s paradox’, in sociological theory [Rig01]. It can be explained as follows: in order to study a social group we need to observe it, but this entails disturbing the group; therefore its cognition is more difficult, sometimes impossible. There is no neutral observation or natural inspection that would leave unchanged the phenomenon being examined. Moreover, the observer involved in a participating observation becomes ‘a fortiori’ an actor, and becomes involved with the participants. What he or she is told, what he or she is given to see, can never be separated from the specific characteristics of the study’s conditions. One way of partially overcoming this paradox is to consider the observed material as being, in part, the results of the study’s conditions and not the immediate representations of a natural reality.

4.5 Boundary conditions of the analysis

The research questions were analysed using survey data from 47 Finns and 51 Italians who worked at CERN over 1990–1999. Following the initial data collection, the author developed the following sampling criteria: for both samples, the respondent’s experience at CERN had to be at least three months’ long and include involvement in developing advanced technology in one or more of the nine industrial sectors electronics, accelerator technology, information-technology, material technology, vacuum technology, medical imaging, mechanics, superconductivity and cryogenics. The Finns’ experience at CERN covered many areas of work and the Italians generally worked in two different areas, the DELPHI experiment and the EST division.

The ten-year time period was chosen so that the setting of the phenomena could be observed as the phenomena studied in this research take significant time to develop. Furthermore, respondents with less than three months’ experience at CERN were excluded from the sample because they were less likely to have developed knowledge and social capital or to have been affected by learning from relationship.

The nine high-technology sectors are appropriate because rapid changes in technological developments in these sectors make knowledge acquisition in exchange relationships particularly salient.

The nine industrial sectors featuring in this study are among the most common sectors studied in research of inter-organizational relationships because of their close collaboration with industry. These sectors offer a very good sampling population at CERN as an example of technology transfer to the private sector and are adequate for cross-science research centre comparisons.

Finnish employees, chosen across all CERN areas of work, represent a sampling population of knowledge acquisition in different domains. The first source of the Italian sample was selected because statistical data and career follow-up was readily available within the DELPHI experiment [Cam96]. The second source was chosen because the EST division has close collaborations with industry and represents a very good example of CERN technology transfer to the private sector. Most of the students who collaborated with this division moved into industry after their studies at CERN.

In this study there are no precise substitutes for many of the critical variables, such as knowledge acquisition, learning, know-how, social capital and technological distinctiveness and no external measures are possible for some, for example, the number of inventions developed explicitly as a result of the relationship between CERN and its users. Because of that, it is necessary to rely on project and group leaders' self-reported assessments for these variables.

5. Statistical considerations

Having discussed the content and purpose of the questionnaire used for this doctoral study in chapter 4, this chapter investigates statistical considerations of the results of that questionnaire.

5.1 Statistics on the Finnish sample

There are 411 Finns recorded in the archives as holding a CERN association between 1990 and 1999 inclusive. This sample has been used for considerations related to age and sex, although the birth date was recorded only for 294 of the sample, thus considerations related to the age at which Finns entered CERN are limited to this statistical sample. Finally, a subset of these 294 Finns replied to the author's questionnaire and these contribute to the statistical evaluation that will be the subject of the next few paragraphs.

5.1.1 Rate of new contracts

The flux of Finns getting a first contract at CERN has remained approximately constant, within the statistical errors, between 1990 and 1999, as shown in Table 5.1. The average yearly rate of new jobs at CERN for Finns during this period equals the total number of jobs taken in the years preceding 1990. This is a clear indication that the official entrance of Finland into CERN as a Member State at the beginning of the 1990s changed the quota of jobs allocated to Finnish citizens. The decrease observed in 1999 can be attributed to the end of the LEP projects and is reflected in a reduced number of contracts across CERN.

Table 5.1: Number of CERN contracts to the Finns per year.

1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
23	43	48	42	40	42	36	41	47	22

Note: total number of contracts = 411

5.1.2 Types of contract

Members of CERN personnel can be divided into three categories based on the type of the contract (Table 5.2) they have with the Organization [CHR99]: first there are those holding an employment contract with the Organization (by CERN referred to as employed members of personnel: Staff Members and Fellows); the second category includes those holding a contract of association with the Organization (referred to as associated members of personnel: Paid and Unpaid Associates, Students, Users, and Project Associates); and third are the Apprentices, holding an apprenticeship contract with the Organization.

Table 5.2: All Staff categories based on the type of CERN contract.

Programme	Requisites	Eligibility conditions	Benefits
The SUMM Programme offers undergraduate students (in physics, computing and engineering) the opportunity to join the research teams participating in CERN experiments. Scientists share their knowledge about topics in theoretical and experimental particle physics and computing. SUMM attend lectures, workshops, discussion and poster sessions, and visit accelerators and experimental areas.	To apply to the Summer Student Programme (SUMM) at least 3 years of undergraduate physics, engineering or computing studies are necessary.		
The TECH Programme is aimed at undergraduate students in technical fields, whose universities require them to spend a training period during their studies in industry or in a research establishment, or also allow them to carry out a project in such an establishment. Only selected students join a team working at CERN.	To apply to the Technical Student Programme (TECH) students must have completed at least 18 months of tehir technical undergraduate studies, and the course requires a practical training period spent at CERN. Note that students of theoretical and experimental particle physics are not eligible for this programme.	Nationality: CERN MS. Qualifications: attendance at an educational establishment of university or advanced technical level in a CERN MS, and participation on a full-time course in one of the following subjects. Study: physics, mathematics, electronic, electrical, accelerator, computing, mechanical and civil engineering, instrumentation for accelerators, geotechenics, and particle physics experiments, low temperature physics and superconductivity, materials science, radiation protection, radio physics and radio chemistry, solid state and surface physics, ultra-high vacuum. Objective: CERN work should be part of the course being studied. Age limit: under 30 years of age at the time of the selection committee meeting. Language: a good knowledge of at least one of the two official languages of CERN, which are English and French. Duration: Appointments may start throughout the year, for at least 6 consecutive months, but for at most 12 months. Students are expected to return to their educational establishment after completion of their CERN stay.	Allowances: CERN pays a subsistence allowance to cover the expenses of a single person in the Geneva area. Insurance: CERN covers medical costs arising from illnesses and accidents of a professional or non-professional nature. Insurance for the consequences of disability and death due to professional or private accidents remains under the responsibility of the students. Travel expenses: Travel expenses to Geneva may be reimbursed for the student only, on the basis of a ticket on the least expensive form of public transport (economy class flight or second class train).

Table 5.2: continued

Programme	Requisites	Eligibility conditions	Benefits
The DOCT Programme is aimed at postgraduate students preparing a doctoral thesis in a technical field. Only selected students join a team working at CERN.	To apply to the Doctoral Student Programme (DOCT) it is necessary to be enrolled in the doctoral programme of a university in a MS, and to wish to spend few months of the thesis work at CERN. This programme is open to students in the scientific and technical fields, except theoretical and experimental particle physics.	Nationality: CERN MS. Qualifications: to be enrolled on the doctoral programme of a CERN MS university in one of the following subjects. Study: as TECH Programme, above. Objective: CERN work should be all or part of the thesis work required to obtain the degree. Daily supervision is the responsibility of a CERN staff member. The award of the degree remains the responsibility of the applicant's university. In each case the academic arrangements discussed between the university and the CERN supervisors. Language: as TECH Programme, above Duration: Doctoral studentships are granted for a period of 12 months initially, normally renewable for a further 12 months. The total period may extend over a maximum duration of 4 consecutive years. The minimum duration of each CERN stay and each period of absence is one month.	Allowances: Students must have financial support (e.g. a grant) from their home country. CERN complements financing in the form of a subsistence allowance during the periods spent at CERN are insured by CERN. Insurance: as TECH Programme, above. Travel expenses: as TECH Programme, above.
Research Fellows in experimental or theoretical physics normally have completed their doctoral studies (Ph.D. or equivalent) while Fellows in applied science, computing and engineering often do not hold such a degree.	The Fellowship Programme (FELL) is intended for young university level postgraduates who would like to have the opportunities, complementary to national schemes, to broaden their knowledge and experience by participating in the research and high-technology activities of the CERN laboratories.	Nationality: CERN MS and in some cases also non-MS. Qualifications: Doctorate in experimental and theoretical physics, a university degree in applied science, computing or engineering. Age limit: not reached 34th birthday at the time of the Selection Committee meeting. Language: as above. Duration: Fellowships are granted for one year and are normally extended for another year, while extensions for part or all of a third year are granted only in exceptional cases.	
The Scientific Associate Programme is open to established scientists and engineers wishing to spend some time at CERN. A large fraction of the Unpaid Associate's time is involved in technical activities in liaison with industry. Theoretical physicists coming for short periods are also included in this sub-category.	The Paid and Unpaid Associates Programmes (PDSA, Paid Scientific Associates, and UPSA, Unpaid Scientific Associates for scientists, engineering and technicians or PDAS, Paid Associates, and UPAS, Unpaid Associates for administrative support employees from external institutions) are open to spend a period learning from or assisting in projects being carried out at CERN.	Nationality: CERN MS and non-MS. Language: as above. Duration: The duration of the contract is at most one year and shall not exceed two years.	
CERN does not have a contract with the individuals concerned, but with the company who employs them. It is however worth noting that many work on the CERN site.	Project Associates (PJAS) are engineers, applied scientists, and technicians who provide expert knowledge on projects concerning CERN accelerators or detector development and/or construction.	Nationality: CERN MS and non-MS. Language: as above. Duration: The duration of association is for an initial period of up to one year, renewable subject to approval by the collaboration institution and cannot be longer than three years.	
Users are generally drawn from various professions, with scientists representing more than 80%.	Many Associates are USERS of CERN who come from universities, institutes and laboratories throughout Europe and, indeed, the world, to propose, install and participate in the physics experiments and in administrative jobs.	Nationality: CERN MS and non-MS Language: as above. Duration: users spend a variable fraction of their working time at CERN.	Allowance: A small number receive a subsistence allowance paid by CERN for periods not exceeding six months.

Table 5.2: continued

Programme	Requisites	Eligibility conditions	Benefits
Staff are distributed into five broad professional categories: research physicists; applied scientists and engineers; technical staff; manual workers and craftsmen; administrators and office staff. Staff are supposed to be highly motivated and able to work in an international and multicultural team.	CERN has a wide variety of staff employment opportunities. Due to the scientific and technical nature of the Organization, the great majority of vacancies are located in the forefront of technical development.	Nationality: CERN MS. Languages: good knowledge of English or French. Basic knowledge of the other language or an undertaking to acquire it rapidly. In the administrative field, language skills are of particular importance. Duration: A contract of three years initially, renewable once for another three years. Holders of such contracts of limited duration may at a later date apply for published vacancies offering so-called fixed-term contracts, which may subsequently lead to the award of an indefinite contract.	Salary: net salary and benefits, including family and child allowances, and partial reimbursement of school fees for dependent children. For staff recruited outside the local region, a non-residence allowance and home leave. Insurance: a comprehensive social coverage scheme, including health insurance and pension fund. Travel: a contribution to joining expenses (travel, installation and removal) as well as a termination indemnity. Living: Switzerland or France. For living in Switzerland, Swiss authorities allow the spouse to work in Switzerland during the contract duration. Assistance in finding accommodation.
ADMI are selected students of international management, finance, personnel and organization. CASS positions are granted to scientists holding research or teaching posts to help them keep abreast of developments in particle physics and related fields.	Other types of contracts are Administrative Student (ADMI), and Corresponding Associate (CASS) programmes.	Nationality: CERN MS. Languages: English or French. Duration: from 6 to 16 weeks for ADMI and 6 months for CASS.	

The different types of contracts held by the Finns are shown in Table 5.3, summarized over the period 1990–1999. The two major percentages are represented by Unpaid Scientific Associate and User contracts. Note that these are the first contracts only, i.e. the contracts issued upon the first appointment at CERN, where this appointment took place in the period covered by this study. Indeed, cases of persons receiving multiple contracts during these years are quite numerous, though these contracts, for each given individual, normally belong to one of the two basic categories, namely administration and research/technology/computing science. The incidence of multiple contracts in the period 1990–1999 is shown in Table 5.4.

It is also worth noting how many of the first contracts gave rise to a subsequent continued relationship with CERN, and with which level of commitment. Of the 49 Summer Students, 11 were subsequently found as researchers at CERN in following years, either as paid or unpaid personnel. Of the 34 persons who got a job as fixed-term staff personnel, 8 envisaged this job as being transformed into a permanent position.

Table 5.3: Types of CERN contracts for the Finnish sample.

SUMM Summer Student	TECH Technical Students	DOCT Doctoral Student	FELL Fellow	PDSA Paid Scientific Associate	PDAS Paid Associate
12%	2%	0%	2%	1%	0%
PJAS Project Associate	**USER Temporary User coming from other Laboratories**	**UPSA Unpaid Scientific Associate**	**UPAS Unpaid Associate**	**STAFF Staff Member**	**OTHER: CASS (Corresponding Associate) ADMI (Administrative Student)**
0%	27%	44%	7%	5%	0%

Note: total number of entries: 411

Table 5.4: Number of CERN contracts for Finnish sample, per person.

1 contract	2 contracts	3 contracts	4 contracts	5 contracts
75%	13%	6%	4%	2%

Note: total number of entries: 411

5.1.3 Distribution according to sex

Of the 411 Finns working at CERN in the period 1990-1999, in total 19% were females and 81% males. The number of women evolved with time, as shown in Table 5.5 for three intervals between 1990 and 1999. Between 1990 and 1999 the female Finnish population largely took the quota of jobs allocated to Finland (mostly staff personnel in Administration).

Table 5.5: Number of Finnish women entering CERN over three periods between 1990 –1999

1990–1992	1993–1996	1997–1999
18	20	21

Table 5.6 represents the percentages of men and women respectively, divided according to category of activity, who entered CERN over three periods between 1990 and 1999. The table 5.6 shows that, even when the number of jobs reached their quota levels between 1997 and 1999 (and the corresponding personnel remained in most cases permanently hired by CERN), the number of females entering CERN did not diminish. Their distribution was simply shifted towards employment (either temporary or fixed terms) in the fields of research, technology and computing science. This is an indication of the ever-growing presence of women in highly qualified activities related to HEP research. The representatives of research represent the majority with respect to the other categories for both men and women.

Table 5.6: Number of Finns (males and females) who entered CERN in three periods, between 1990 and 1999, divided according to field of employment.

	1990–1992		1993–1996		1997–1999	
	Men	**Women**	**Men**	**Women**	**Men**	**Women**
Research	58	9	101	15	73	21
Technology	16	2	9	2	9	4
Computing science	14	2	7	1	7	0
Administration	6	7	8	12	0	0

5.1.4 Distribution according to age

The date of birth was recorded for only 294 of the 411 Finns whose records were stored in the CERN archive. The plot shown in Fig. 5.1 reflects the distribution of age at which the first contract was undertaken for these 294 Finns.

The distribution in Figure 5.1 is derived from Table 5.7, which gives details of the kind of contracts issued. It may be noted that age at the first contract peaked at around 24 years. This could be a reflection of the fact that many physics students come to CERN to prepare their doctoral thesis, not as Summer Students.

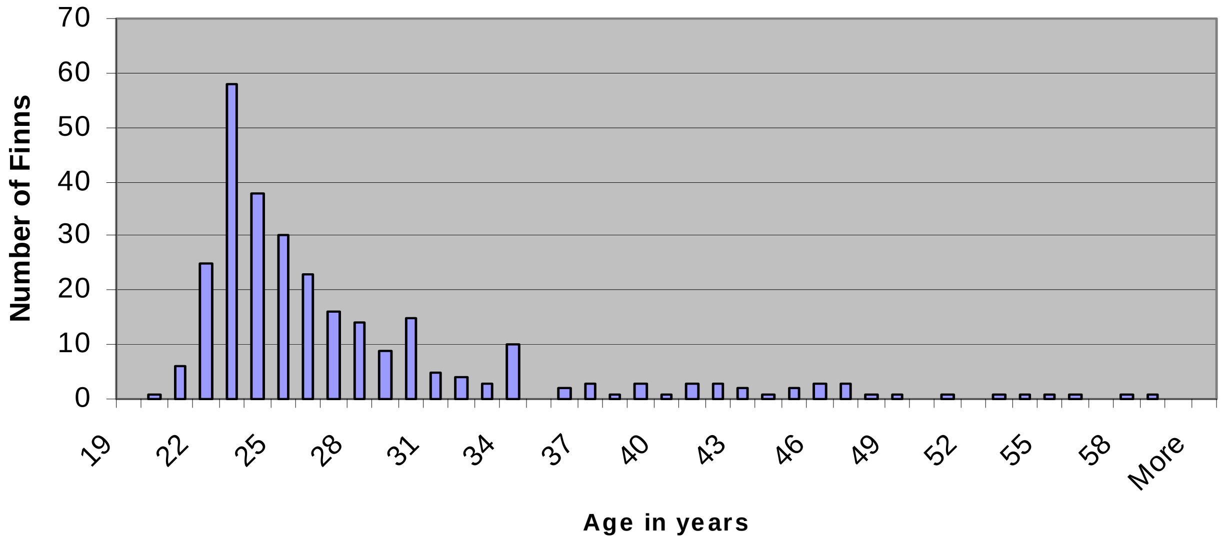


Fig. 5.1: Age distribution of the Finns at the time of the first CERN contract. Number = 294.

Table 5.7: Age of the Finns at the time of the first contract. Number = 294.

AGE	TYPE OF CONTRACT						TOTAL
20	1 USER						1
21	1 SUMM	2 UPSA	3 USER				6
22	6 SUMM	11 UPSA	3 UPAS	5 USER			25
23	18 SUMM	4 TECH	20 UPSA	4 UPAS	11 USER	1 STAF	58
24	11 SUMM	1 TECH	18 UPSA	2 UPAS	1 STAF	6 USER	39
25	4 SUMM	1 TECH	1 DOCT	15 UPSA	4 UPAS	5 USER	30
26	1 SUMM	1 TECH	13 UPSA	1 UPAS	6 USER	1 STAF	23
27	1 SUMM	1 TECH	10 UPSA	1 UPAS	3 USER		16
28	1 DOCT	1 FELL	5 UPSA	3 UPAS	3 USER	1 STAF	14
29	1 FELL	3 UPSA	2 UPAS	1 USER	2 STAF		9
30	1 TECH	1 FELL	7 UPSA	1 UPAS	1 PDSA	4 STAF	15
31	4 UPSA	1 USER					5
32	3 UPSA	1 STAF					4
33	1 UPSA	1 UPAS	1 USER				3
34	7 UPSA	1 UPAS	1 USER	1 STAF			10
35	0						0
36	1 UPSA	1 STAF					2
37	3 UPSA						3
38	1 STAF						1
39	1 UPSA	1 UPAS	1 PDSA				3
40	1 UPSA						1
41	1 UPSA	1 UPAS	1 USER				3
42	3 UPSA						3
43	2 UPSA						2
44	1 UPAS						1
45	1 UPSA	1 STAF					2
46	1 UPSA	1 USER	1 STAF				3
47	1 UPSA	1 UPAS	1 USER				3
48	1 USER						1
49	1 UPSA						1
50	0						0
51	1 UPSA						1
52	0						0
53	1 FELL						1
54	1 UPSA						1
55	1 USER						1
56	1 UPAS						1
57	0						0
58	1 UPSA						1
59	1 USER						1
60	0						0

5.2 Statistics on the responses

Of the 411 individuals of the Finns sample, data for 198 were available from the CERN archives and for 213 from the CERN Human Resources database. Thirty-four questionnaires of the 213 sent by electronic mail were returned because of unknown electronic addresses. This means that in total 179 questionnaires were received by e-mail. In addition, 69 questionnaires out of the 198 sent by mail were returned: 27 because the recipient was unknown at the indicated address, 35 because the recipient had moved from the indicated address and seven for both reasons. This means that in total 129 questionnaires can be assumed to have been received by mail. The total estimated number of questionnaires received by Finns is 308 (179 via e-mail and 129 via mail).

Of the 106 individuals of the Italian sample: 10 questionnaires out of 101 sent by electronic mail were returned because of unknown electronic address. Therefore 91 questionnaires in total were received by e-mail. In addition, one questionnaire of the five sent by mail was returned because the recipient was unknown. This means that in total 95 (91 via e-mail and 4 via mail) can be assumed to have been received by the Italians.

The total number of replies to the questionnaire was 98: 47 were received from Finns (35 via the Web, 7 via interviews and 4 via mail), and 51 were received from Italians (34 via the Web, 16 via interviews and 1 via mail). This total can be considered to be the total of the statistical sample in order to start analysis for the final study.

5.2.1 Types of contract

The incidence of multiple contracts and the different types of contracts held by the Finns and Italians are shown for the period 1990–1999 in Table 5.8 and in Table 5.9. Note that in Table 5.9 the first contracts only are included, i.e. the kind of contract that was issued at the first appointment with CERN, if this appointment took place in the period covered by this study. The total number of entries in these plots is 47 for Finns and 51 for Italians. The cases of persons holding multiple contracts over these years normally occur in the same basic categories, namely physics, engineering, and administration for Finns and physics and engineering for Italians.[1] The current professional position for Finns and Italians is shown in Table 5.10. Among the 15 Finnish university staff, 13 are still in contact with CERN; among the 11 Italian university and INFN (Istituto Nazionale di Fisica Nucleare) staff, 9 are still in contact with the laboratory.

Table 5.8: Number of contracts per person

Contracts	**Finns** (n=47)	**Italians** (n=51)
1	26	18
2	8	15
3	10	9
4	2	8
5	1	1

Table 5.9: Type of contract at the first contract

Type of contract	**Finns**	**Italians**
SUMM: Summer Student	9	2
TECH: Technical Student	4	7
DOCT: Doctoral Student	0	0
FELL: Fellow	4	0
PDSA: Paid Scientific Associate	3	1
PDAS: Paid Associate	0	0
PJSA: Project Associate	0	0
USER: Temporary User coming from other Laboratories	6	12
UPSA: Unpaid Scientific Associate	12	25
UPAS: Unpaid Associate	4	0
STAFF: Staff Member	4	0
OTHER: CASS (Corresponding Associate) and ADMI (Administrative Student)	1	0

Table 5.10: Current professional position

Work Position	**Finns 47**	**Italians 51**
Firms	14	14
International research centre	3	7
CERN Staff	10	12
Finnish university staff	15	—
Italian university & INFN staff	—	11
CERN-HIP Students	5	—
CERN-IT UNIVERSITY students	—	7

Note: HIP = Helsinki Institute of Physics

5.2.2 Distribution according to sex

Of the 47 Finns who answered the questionnaire, 19% were female and 81% male, the same percentage as for the total sample of Finns at CERN 1990–1999. In the Italian sample 22% are female and 78% male. Tables 5.11 and 5.12 show the number of Finns and Italians (male and female) who answered the questionnaire and

[1] There are only two categories for the Italian sample because it was drawn from two scientific and technological sources: physicists from the DELPHI experiment and engineers from the EST division.

entered CERN over the three periods between 1990 and 1999, divided according to category of activity.

Interestingly, as shown in Table 5.11, when these job quotas were reached, the number of Finnish females entering CERN in the years 1997-1999 did not diminish, confirming the previous statistics (see Tables 5.5 and 5.6). Their distribution was simply shifted towards employment (either temporary or fixed term) in physics, engineering, and administration.

The number of Italian females shows a decrease over the same period. As with the Finns, the female Italian population largely took the quota of jobs allocated to Italy, but, as shown in Table 5.12, when the quota was saturated in years 1997-1999, the number of Italian females entering CERN diminished. Their distribution was shifted towards employment (either temporary or fixed term) in the fields of physics and engineering, with the main shift towards the physics domain.

Table 5.11: Finns answering the questionnaire who entered CERN 1990–1999.

	before 1990		**1990–1992**		**1993–1996**		**1997–1999**	
	Men	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**
Physicists	4	2	2	0	6	0	9	0
Engineers	0	0	3	0	5	1	6	3
Administrators	1	0	1	1	1	1	0	1

Note: total number of men=38; total number of women = 9

Table 5.12: Italians answering the questionnaire who entered CERN 1990-1999.

	before 1990		**1990–1992**		**1993–1996**		**1997–1999**	
	Men	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**
Physicists	7	3	6	1	10	4	4	2
Engineers	1	0	1	0	8	0	3	1

Note: total number of men=40; total number of women = 11

5.2.3 Distribution according to age

For all 47 Finns and 51 Italians in the sample their date of birth was recorded. This is plotted in Fig. 5.2. The shape of the Gaussian fit of the data reflects the shape of the distribution of the age at which the first contract was undertaken. Purely by observation what appears to be reasonable, although no formal proof has been made. It may be noted that the age of the first contract peaks at around 25 years both for Finns and for Italians. This suggests that the number of Unpaid Scientific Associates (UPSA) shown in Table 5.9 could be an indication that many students come to CERN to prepare their final university thesis, though not always as Summer Students or

Technical Students. These results for the Finnish sample confirm what found in the analysis carried out on the initial database.

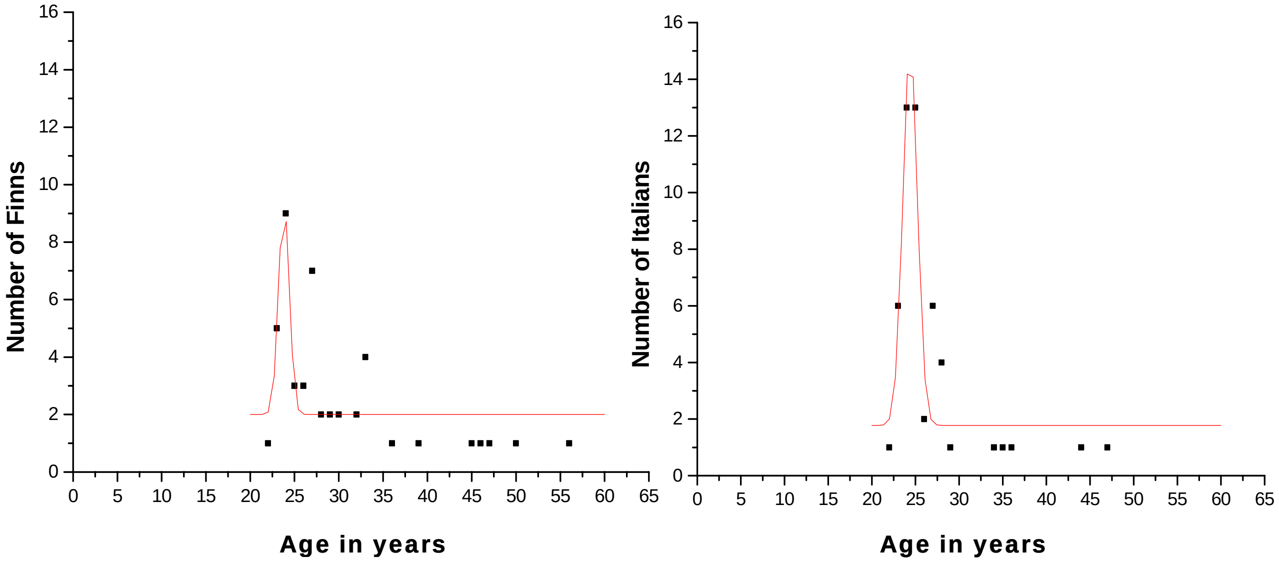


Fig.5.2: Age distribution at the time of the first contract for the final samples. Number of entries: 47 Finns and 51 Italians.

5.2.4 Background statistics on responses

Statistics for the replies to the first 20 questions on the questionnaire are shown in Figures 5.3a, 5.3b for the Finns, and in Figures 5.4a, 5.4b for the Italians. Distributions are derived from Tables 5.13a and 5.13b. The underlying analysis is based on a sample comprising two categories of employees: Finnish employees across all fields, and Italians drawn from two sources: physicists who participated in the DELPHI experiment, and engineers who have worked in the EST division. Question 21, which is of sociological interest and aims to determine whether the stay at CERN modified any cultural habits and facilitated cross-cultural know-how acquisition, will be dealt with later.

In total, five Italians (four physicists and one engineer, aged between 23 and 27), and two Finns (one physicist and one engineer, 23 and 25 years old) answered all the questions. Two Italian physicists and nine Finns (six physicists, one engineer and two administrators) answered fewer than half of the questions in the questionnaire. Two administrators in the Finnish sample answered only one question.

With regard to the Finnish sample, Question 7, which analyses the impact of working in the CERN international environment, received two ‘no answer’. Question

1, which invites respondents to quantify their most important scientific and technical contribution whilst at CERN, received six 'no answer'. Questions 10 and 12, both referring to users' expectations not satisfied by CERN, received 32 and 28 'no answer'. The situation for the Italian sample is different. In particular, all Italians answered Question 1. All, except one, answered Question 7 and 2, concerning overall knowledge acquisition. Questions 10 and 12 received few replies (26 and 21 'no answer' respectively).

Table 5.13a: Number of responses. Finnish sample: 47 Finns.

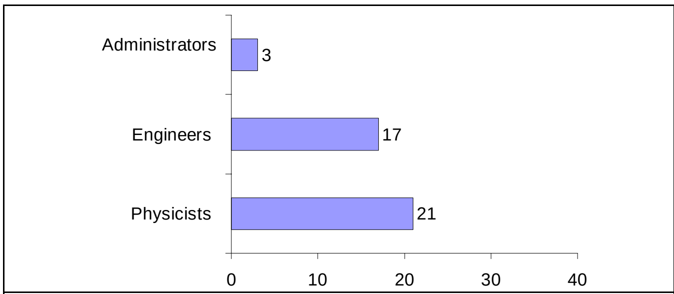
Question	Physicists M+F	Engineers M+F	Administrators M+F	Total answers %	No answer M+F	Total 38M+9F
Q_1	21 = 19+2	17 = 13+4	3 = 2+1	87	6 = 4+6	47
Q_2	20 = 18+2	13 = 9+4	2 = 2+0	74	12 = 9+3	47
Q_3	20 = 18+2	15 = 12+3	3 = 1+2	81	9 = 7+2	47
Q_4	17 = 16+1	13 = 10+3	2 = 1+1	68	15 = 11+4	47
Q_5	12 = 12+0	11 = 8 +3	2 = 1+1	53	22 = 17+5	47
Q_6	13 = 11+2	15 = 11+4	2 = 2+0	64	17 = 14+3	47
Q_7	23 = 21+2	18 = 16+4	4 = 2+2	96	2 = 1+1	47
Q_8	15 = 13+2	15 = 11+4	2 = 1+1	68	15 = 13+2	47
Q_9	12 = 10+2	12 = 9+3	2 = 1+1	56	21 = 18+3	47
Q_{10}	6 = 5+1	7 = 5+2	2 = 1+1	32	32 = 27+5	47
Q_{11}	21 = 19+2	15 = 11+4	3 = 1+3	83	8 = 7+1	47
Q_{12}	8 = 7+1	8 = 5+3	3 = 1+2	40	28 = 25+3	47
Q_{13}	16 = 14+2	12 = 9+3	2 = 1+1	64	17 = 14+3	47
Q_{14}	16 = 14+2	15 = 12+3	2 = 0+2	70	14 = 12+2	47
Q_{15}	15 = 13+2	16 = 13+3	3 = 2+1	72	13 = 10+3	47
Q_{16}	21 = 19+2	14 = 11+3	2 = 1+1	79	10 = 7+3	47
Q_{17}	21 = 19+2	12 = 8+4	1 = 1+0	72	13 = 10+3	47
Q_{18}	17 = 15+2	12 = 10+2	3 = 2+1	68	15 = 11+4	47
Q_{19}	16 = 14+2	14 = 11+3	1 = 1+0	66	16 = 12+4	47
Q_{20}	19 = 17+2	15 = 13+2	2 = 1+1	77	11 = 7+4	47

Note: M = male, F = female

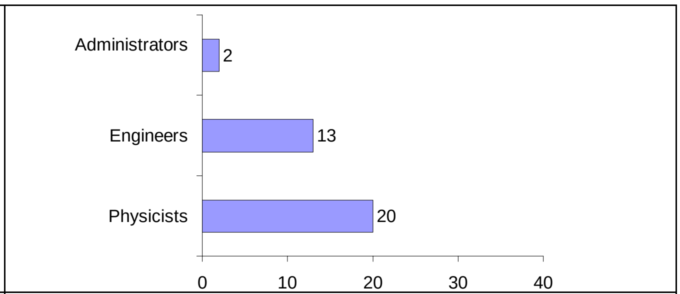
Table 5.13b: Number of responses. Italian sample: 51 Italians.

Question	Physicists M+F	Engineers M+F	Total answer %	No answer M+F	Total 40M+11F
Q_1	37 = 28+9	14 = 12+2	100	0 = 0+0	51
Q_2	36 = 26+10	14 = 13+1	98	1 = 1+ 0	51
Q_3	36 = 26+10	13 = 12+1	96	2 = 2+0	51
Q_4	29 = 20+9	11 = 11+0	78	11 = 9+2	51
Q_5	25 = 18+7	10 = 10+0	69	16 = 12+4	51
Q_6	30 = 21+9	10 = 10+0	78	11 = 9+2	51
Q_7	36 = 27+9	14 =13+1	98	1 = 0+1	51
Q_8	31 = 23+8	9 = 8+1	68	11 = 9+2	51
Q_9	26 = 19+7	11 = 10+1	73	14 = 11+3	51
Q_{10}	21 = 18+3	4 = 4+0	49	26 = 18+8	51
Q_{11}	33 = 24+9	12 = 11+1	88	6 = 5+1	51
Q_{12}	24 = 17+7	6 = 5+1	59	21 = 18+3	51
Q_{13}	26 = 18+8	12 = 11+1	75	13 = 11+2	51
Q_{14}	35 = 25+10	13 = 12+1	94	3 = 3+0	51
Q_{15}	33 = 23+10	11 = 11+1	86	7 = 7+0	51
Q_{16}	34 = 25+9	14 = 13+1	94	3 = 2+1	51
Q_{17}	31 = 24+7	14 = 13+1	88	6 = 3+3	51
Q_{18}	32 = 23+9	14 =13+1	90	5 = 4+1	51
Q_{19}	33 = 23+10	13 = 12+1	90	5 = 5+0	51
Q_{20}	31 = 21+10	10 = 10+0	80	10 = 9+1	51

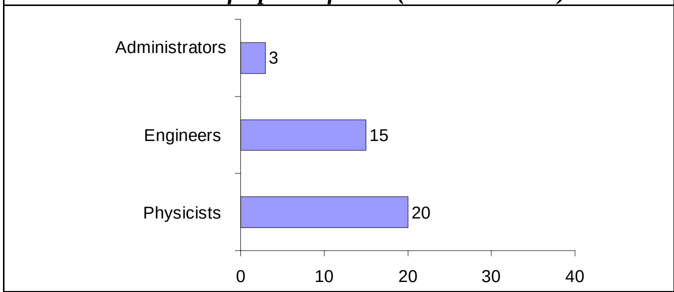
Note: M = male, F = female



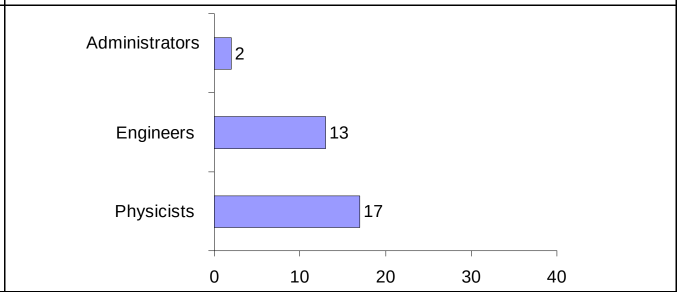
Q_1: Your most important contribution from a technical or a scientific point of view. (No answers = 6)



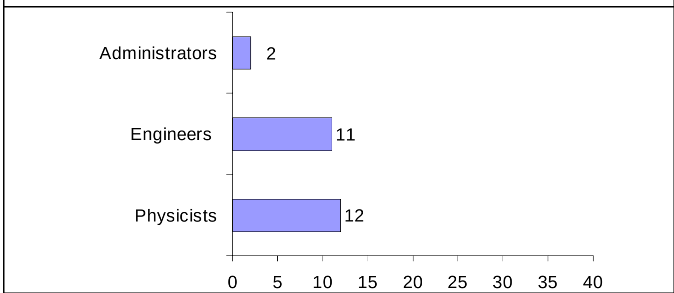
Q_2: Acquired knowledge. (No answers = 12)



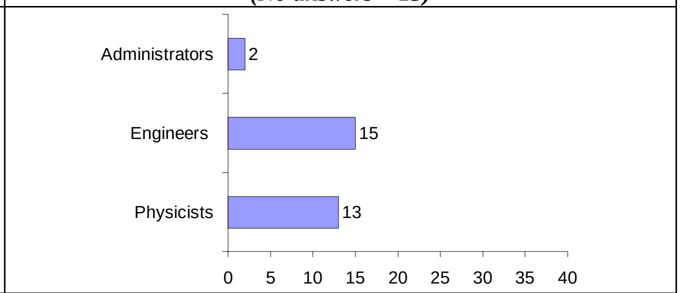
Q_3: Acquired knowledge per topic. (No answers = 9)



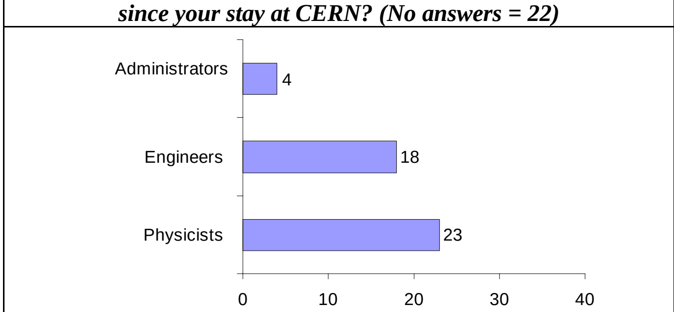
Q_4: List the fields of interest developed or topics studied by interacting with colleagues at CERN or outside CERN. (No answers = 15)



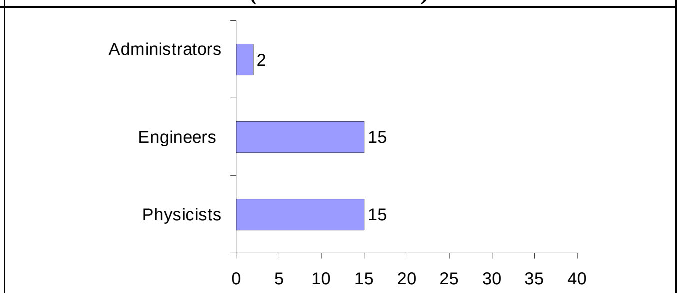
Q_5: Which field of Q_4 have you put into practice since your stay at CERN? (No answers = 22)



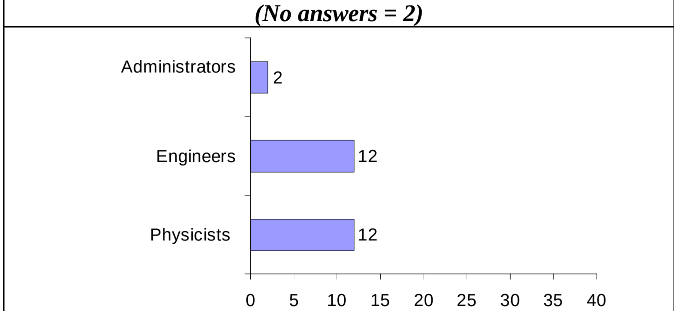
Q_6: Which of Q_5 has proved the most useful? (No answers = 17)



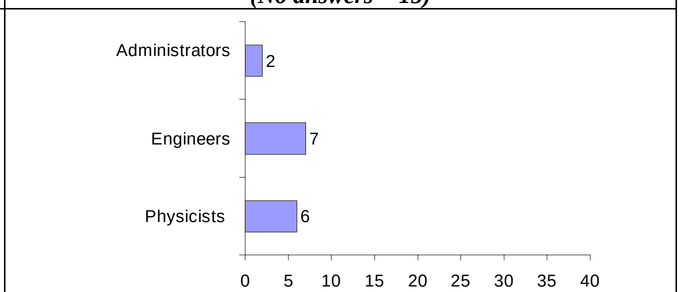
Q_7: Impact of working in an international environment. (No answers = 2)



Q_8: Impact of training. (No answers = 15)

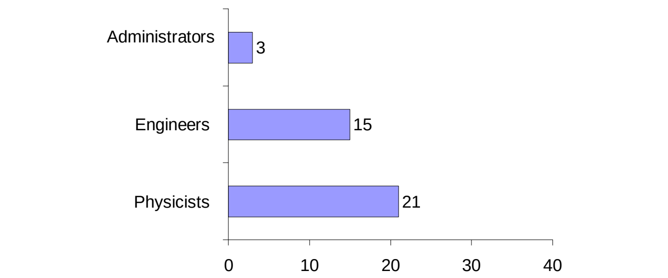


Q_9: Which lectures impressed you most? (No answers = 21)

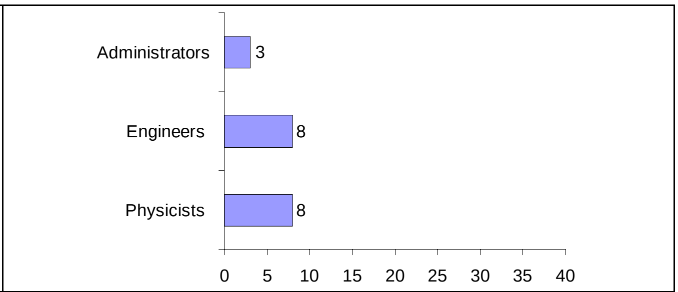


Q_{10}: Which skills did you expect to develop or acquire but were unable to? (No answers = 32)

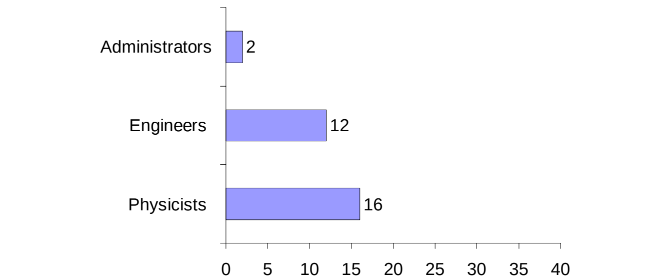
Fig.5.3a: Statistics on Finnish replies to Questions 1 to 10 ($Q_1 - Q_{10}$).



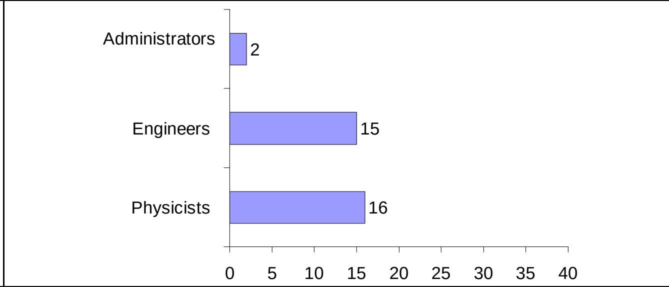
Q_{11}: The multicultural aspects of CERN influenced your career development? (No answers = 8)



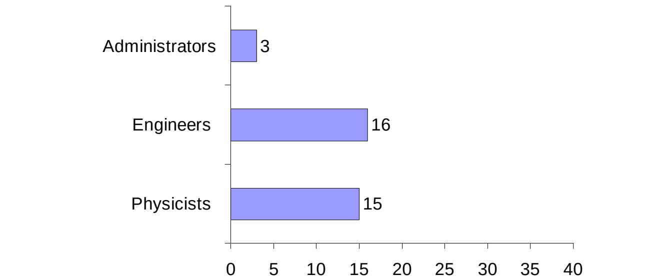
Q_{12}: Which fields or subjects did not meet your expectations? (No answers = 28)



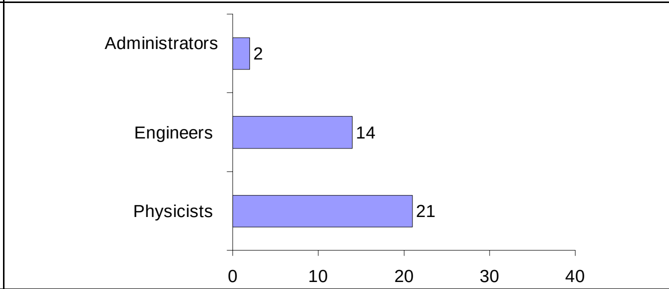
Q_{13}: What did you consider negative? (No answers = 17)



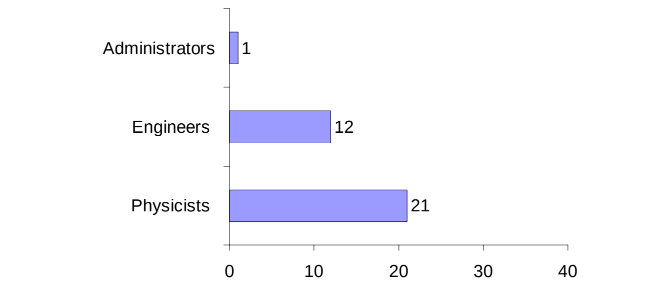
Q_{14}: What was most important for your personal development? (No answers = 14)



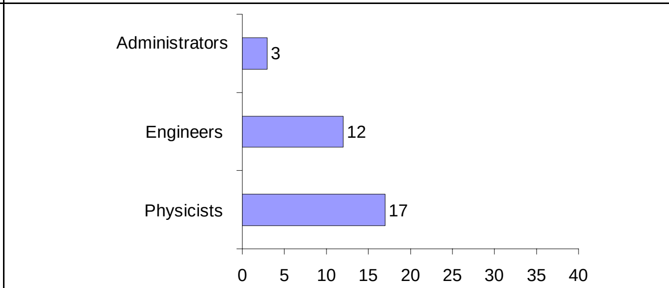
Q_{15}: Which technology acquired or skill improved at CERN has had the greatest impact on your career? (No answers = 13)



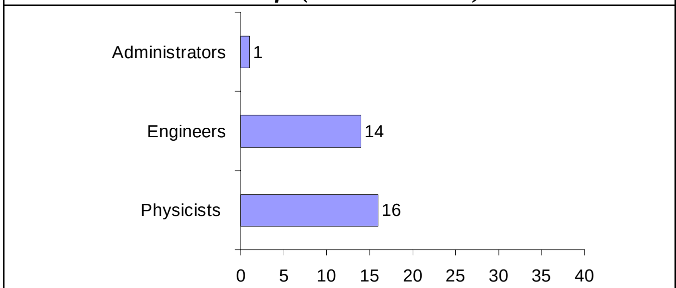
Q_{16}: Participation in R&D project. (No answers = 10)



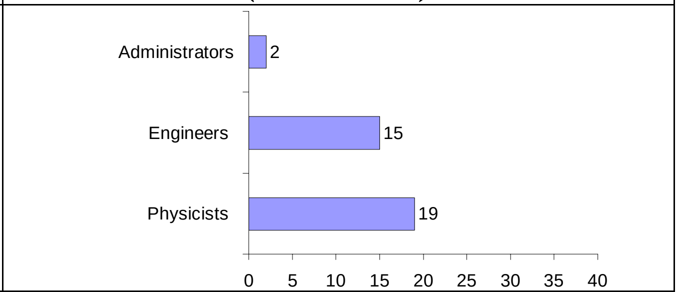
Q_{17}: Was there any technological return or application you are aware of? (No answers = 13)



Q_{18}: Positive or negative experience meetings. (No answers = 15)

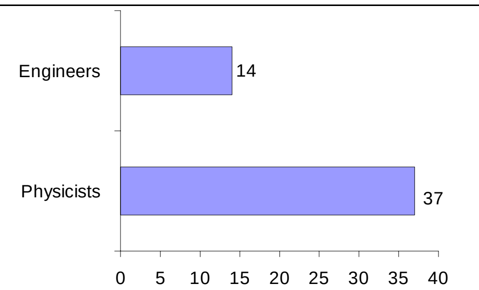


Q_{19}: Outline the difference between work and CERN experience for the learning process acquisition. (No answers = 16)

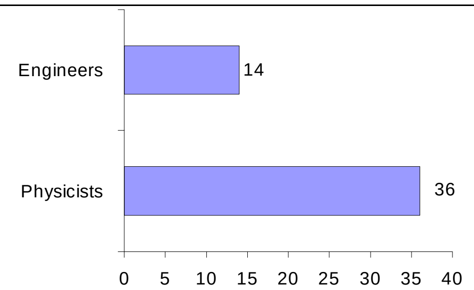


Q_{20}: Have you obtained a position thanks to the experience acquired at CERN? (No answers = 11)

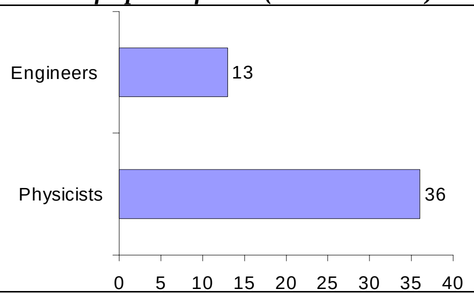
Fig.5.3b: Statistics on Finnish replies to Questions 11 to 20 (Q_{11} – Q_{20}).



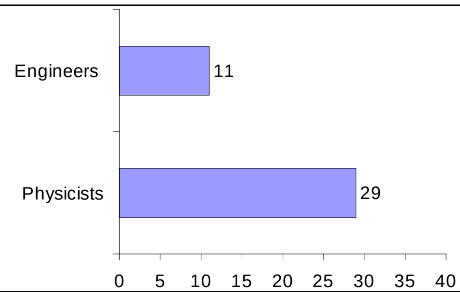
Q_1: Your most important contribution from a technical or a scientific point of view. (No answers = 0)



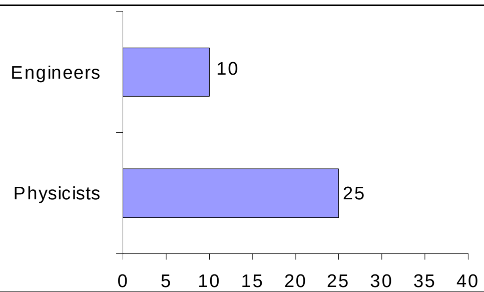
Q_2: Acquired knowledge. (No answers = 1)



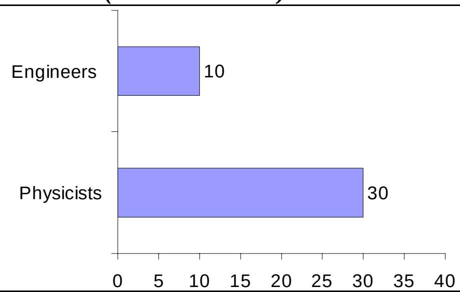
Q_3: Acquired knowledge per topic. (No answers = 2)



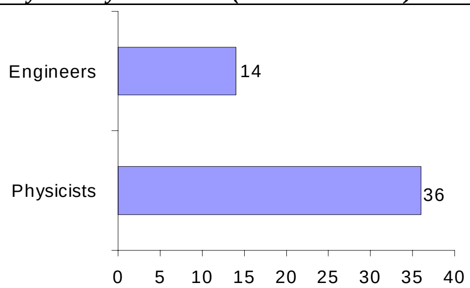
Q_4: List the fields of interest developed or topics studied by interacting with colleagues at CERN or outside CERN. (No answers = 11)



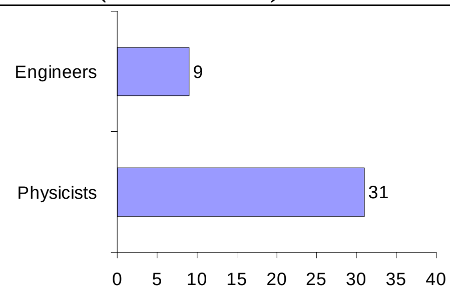
Q_5: Which field of Q_4 have you put into practice since your stay at CERN? (No answers = 16)



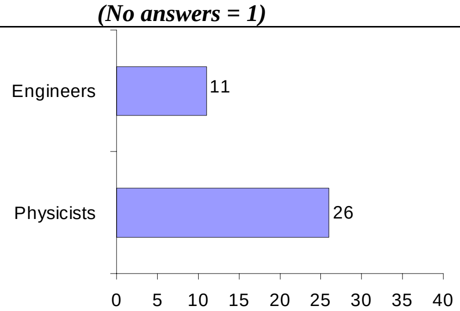
Q_6: Which of Q_5 has proved the most useful? (No answers = 11)



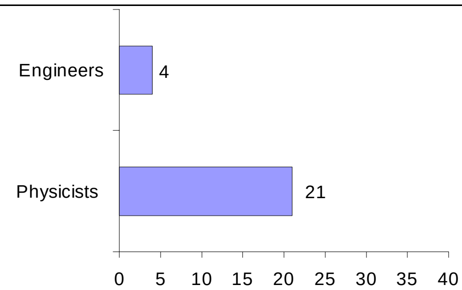
Q_7: Impact of working in an international environment. (No answers = 1)



Q_8: Impact of training. (No answers = 11)

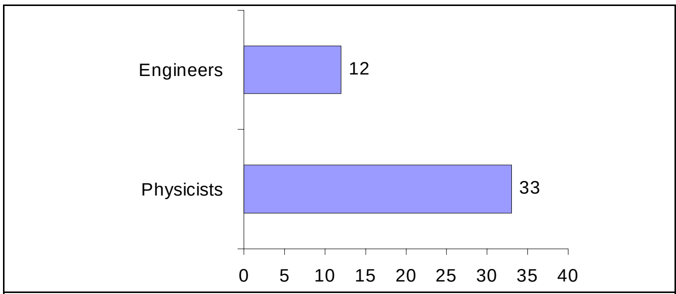


Q_9: Which lectures impressed you most? (No answers = 14)

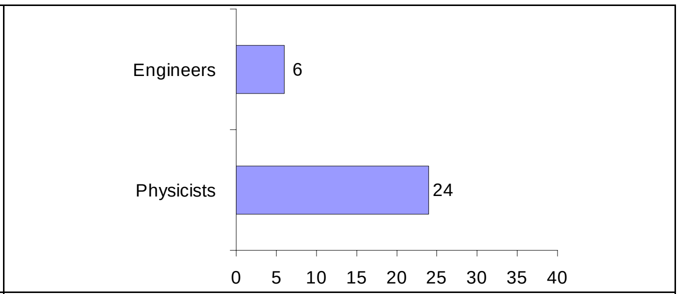


Q_{10}: Which skills did you expect to develop or acquire but were unable to? (No answers = 26)

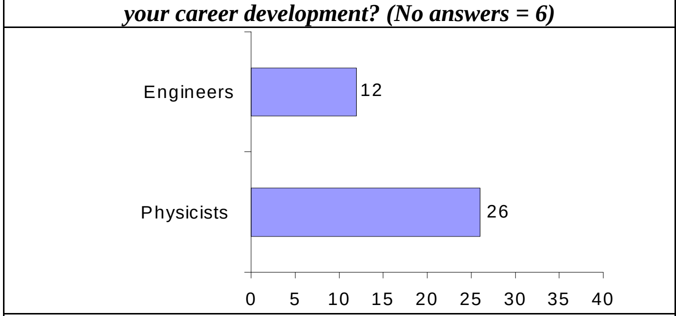
Fig.5.4a: Statistics on Italian replies to Questions 1 to 10 ($Q_1 – Q_{10}$).



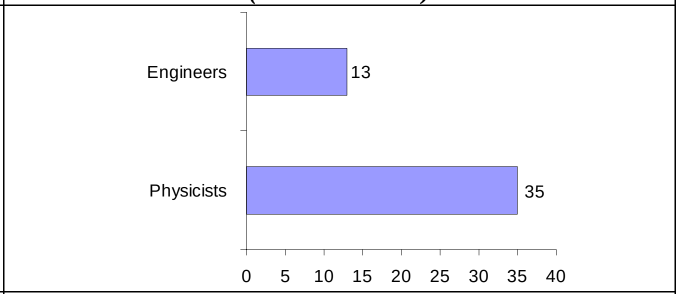
Q_{11}: Have the multicultural aspects of CERN influenced your career development? (No answers = 6)



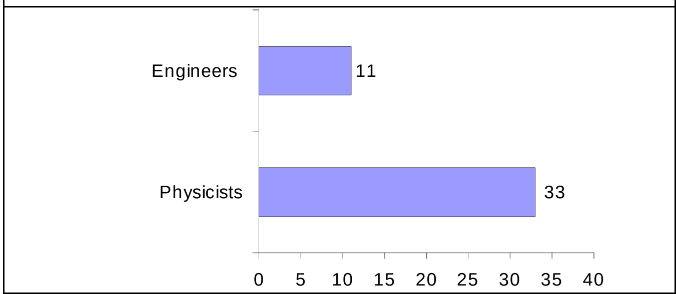
Q_{12}: Which fields or subjects did not meet your expectations? (No answers = 21)



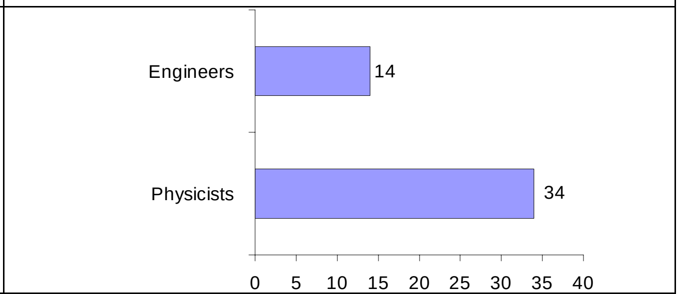
Q_{13}: What did you consider negative? (No answers = 13)



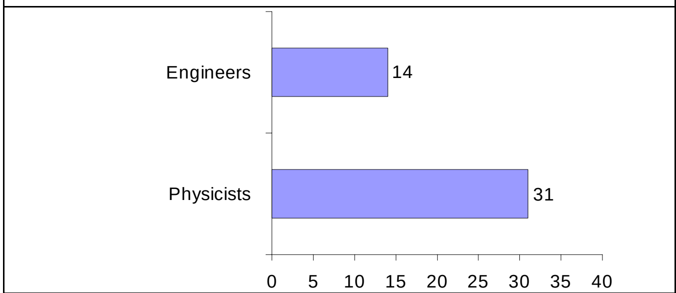
Q_{14}: What was most important for your personal development? (No answers = 3)



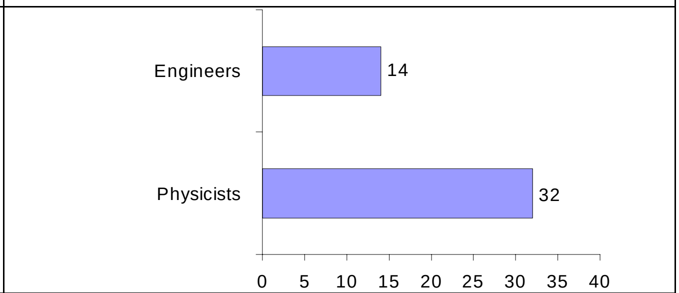
Q_{15}: Which technology acquired or skill improved at CERN has had the greatest impact on your career? (No answers = 7)



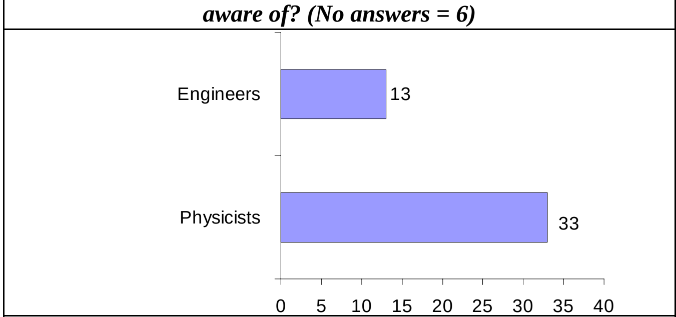
Q_{16}: Participation in R&D project. (No answers = 3)



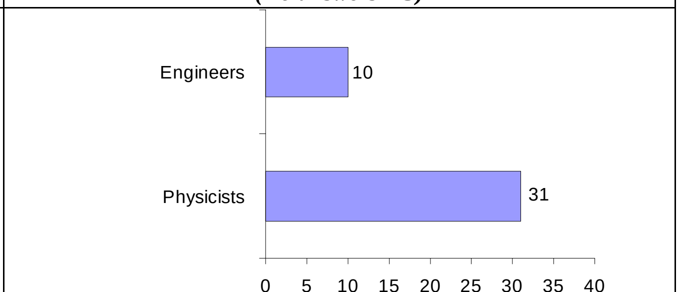
Q17: Was there any technological return or application you are aware of? (No answers = 6)



Q_{18}: Positive or negative experience of meetings. (No answers = 5)



Q_{19}: Outline the difference between work and CERN experience for the learning process acquisition. (No answers = 5)



Q_{20}: Have you obtained a position thanks to the experience acquired at CERN? (No answers = 10)

Fig.5.4b. Statistics on Italian replies to Questions 11 to 20 ($Q_{11} – Q_{20}$).

6. Research questions and data analysis

After having introduced the process of technology transfer and the context in which it is carried out at CERN (Chapter 2), having constructed an appropriate model for technology transfer (Chapter 3), having prepared a Web-based questionnaire for the collection of the data analysed in the model construction (Chapter 4), and presented its statistical considerations (Chapter 5), this chapter discusses research questions and analyses the results of the questionnaire.

6.1 Theoretical framework and research questions

This work surveys the acquisition of knowledge in CERN, employing a sample of 411 Finns and 106 Italians who worked at the laboratory during a ten-year period (1990–1999). In particular, as mentioned before, it aims to answer two main questions. The first addresses the educational impact of CERN for students and apprentices. A related aspect is the competitive core skills and acquired knowledge people develop and the market value of these skills for Member States' industries. The second question is how exposure of people to an international environment enhances their cultural and social dimensions and how society benefits from this exposure. In addition, the correlation between knowledge acquisition and competitive advantage between CERN and its users is analysed. The analysis is based on the model developed in Chapter 3.

The following background surveys were carried out for this research:

a) an analysis of CERN-specific needs regarding educational impact and technology transfer through people, in particular the collection of information with the aim of defining parameters for an alumni database;

b) a comparative study of alumni databases from different sources (universities, research centres, etc.) highlighting the main common parameters;

c) an attempt to create a mechanism which identifies qualified personnel and possible spin-offs[1] in a given area of knowledge; and

d) an analysis of information on the type and quality of education and technical training acquired at CERN and an evaluation of its educational impact.

[1] See Section 2.3.7.

An organization acquires knowledge if any of its units acquire knowledge recognized as potentially useful to the organization. As mentioned in the previous Chapters, recent studies have proposed that inter-organizational relationships create opportunities for knowledge acquisition, exploitation and transfer. Through interaction with others, organization members gain access to external and explicit knowledge and combine it with existing and tacit knowledge. Furthermore, such relationships create a context within which newly created knowledge can be applied and exploited. A premise of this argument is that the more social capital (see Section 3.4) a user develops in the relationship, the more likely he or she is to acquire new knowledge and exploit it as a basis for competitive advantage. The potential an individual has to create competitive advantage depends not just on his or her own resources but also on his or her relationships with other users. One of the potential sources of inter-organizational competitive advantage is knowledge sharing. The extent to which a user can acquire knowledge from a research organization such as CERN depends on the existence of knowledge; on the ability of the user to recognize and assess the value of the knowledge; on the frequency and the intensity of interaction; and on the willingness of the users to share information.

CERN can in itself be considered a learning organization where organizational knowledge created within the organization is shared and transferred both inside the organization and across the different fields of technological competences as well as the institutions within the laboratory. This aspect will also be analysed using the research sub-questions.

Before introducing the research sub-questions, it is important to note that the questionnaire pays attention to a set of CERN procedures concerning the social process and to different quality aspects of these procedures, like internationality, multiculturality and the individual’s position in the competence hierarchy. Participation in meetings and interacting with colleagues are some of several important aspects of knowledge acquisition. In principle the questionnaire provides information on the effectiveness of any of these procedures and on the importance of the different quality aspects.

6.1.1 Individual knowledge acquisition

Sense perception, learning, studying, research and science are different stages of the same process, that of the creation of knowledge, which is a personal process for everyone. Learning is an intuitive perceptional process, which leads to permanent knowledge. The quantification process is an important element of conceptual development in the learning of physics. This makes physics different from all other branches of science, and the learning of physics different from any other learning as it is a highly structured perception process.

The knowledge learning process is analysed in terms of three basic mutually dependent and inseparably interconnected process elements: the scientific process and the technological process, which are mediated by the social process. The scientific process builds the concepts of the world for understanding natural phenomena, the technological process changes the structure of the world for satisfying uses and needs, and the social process negotiates the meanings for finding general agreement. The scientific and technological processes form, as results, concepts and products, respectively and both are sources of science and technology, which are manifested through methods and procedures, and are strictly interconnected. Every concept has both a scientific and a technological meaning, agreed in the social process. This social process extends individual cognition into shared social understanding and creates common concepts.

This leads to research sub-question 1: *is participation in meetings a procedure of the social process which is effective in advancing the scientific and technological processes*?

6.1.2 Organizational knowledge acquisition

Learning organizations are shared meaning systems. Knowledge has to be built on its own, frequently requiring intensive and laborious social interaction among members of the organization, which has to provide a shared context for this interaction. Knowledge cannot be created without intensive outside-inside interaction, in which an individual's personal knowledge is transformed into organizational knowledge, valuable to the organization as a whole.

The organizational knowledge creation approach focuses on knowledge sharing and knowledge transfer inside an organization, which is not a machine for processing information but a living organism, where everyone is a knowledge worker. It considers how knowledge is created and how the knowledge creation process is managed. It is a dynamic model anchored in the assumption that human knowledge is created and expanded through social interaction between tacit knowledge and explicit knowledge. This interaction, called knowledge conversion, is a social process carried out between individuals through four different modes: socialization, externalization, combination and internalization. When experience through socialization, externalization and combination is internalized into individuals' tacit knowledge bases in the form of shared mental models or technical know-how, they become valuable assets.

This leads to research sub-question 2: ***are the acquisition of skills in different topics and the development of interests by interaction with colleagues important indicators of effective scientific and technological processes?***

6.1.3 Knowledge acquisition and social capital

Social capital facilitates knowledge acquisition by affecting the conditions necessary for the exchange and combination of existing intellectual resources. If and how a CERN user can realize knowledge acquisition depends on three aspects of social capital in the users' relationships: the social interaction between the users, the quality of the relationships in terms of goodwill, trust and reciprocity, and the network ties created through the relationships. Social capital enhances knowledge acquisition by improving access to external sources of knowledge, by increasing the willingness and ability of exchange partners to identify, exchange and assimilate knowledge, and by improving the breadth and efficiency of knowledge transfer. Building on social capital and knowledge-based theories, it is proposed that social capital facilitates knowledge acquisition in the relationship between CERN and its users, and that this knowledge leads to competitive advantage through enhanced capability for value creation.

Social interaction builds up the intensity, frequency and breadth of information exchanged. While explicit knowledge may be relatively easy to obtain through passive efforts such as reading trade journals, or more active methods such as benchmarking, interactive learning allows people to get close enough to acquire not just the observable, but also the deeper, tacit components of knowledge. Not only should social interaction facilitate knowledge acquisition by creating intense, repeated interaction, but it should also enhance users' ability to recognize and evaluate the pertinent external knowledge of CERN. Social interaction provides users with insight into the specialized systems and structures of CERN and results in specialized information, language and know-how. In essence, social interaction provides better access to and understanding of CERN operations and more effective means of communicating with all CERN people. By intensifying the frequency, breadth and depth of information exchange, social interaction increases relation-specific common knowledge. Because communication efficiency is enhanced through repeated social interaction, both parties have a greater incentive to invest even more in knowledge-sharing routines. By intensifying knowledge-sharing activities, social interaction serves to increase the relative capacity and effectiveness of a user in recognizing and adapting external knowledge from CERN and both parties thereby become more willing to invest further in the transfer and creation of new knowledge.

This leads to research sub-question 3a: ***if the social interaction between CERN and its users is stronger, will the knowledge acquisition of users be greater*****?**

Because the costs of sharing know-how in interorganizational relationships are high, effective mechanisms must be in place to encourage knowledge sharing. According to the theoretical framework, self-enforcing governance mechanisms, such as informal norms of reciprocity, goodwill, and trust are most effective at encouraging knowledge sharing. Establishing high levels of mutual expectation should enhance knowledge acquisition because it demands the compatibility of the systems and cultures. Relative absorptive capacity is greatest when exchange partners have similar expectations and systems, because knowledge is embedded in the systems themselves. Relations based on reciprocity and trust also reduce the time spent on monitoring and bargaining over agreement. Everything being equal, less time wasted in bargaining and monitoring can mean greater time devoted to information processing and exchange. Furthermore, because the other party can be trusted to look out for the good of the exchange partner and to be flexible about changes in circumstances, the scope of relational learning broadens; the incentive to try new things, to experiment and to take risks in sharing information is enhanced. To sum up, the quality of the relationship between CERN and its users should be positively associated with knowledge acquisition because it provides control, increases mutual understanding, quickens exchange processes and encourages freedom in exchange.

This leads to research sub-question 3b: *if the quality of the relationship between CERN and its users is higher, will the knowledge acquisition of the users be greater?*

Diversity is necessary for new knowledge creation; it exposes users to a greater range of knowledge acquisition opportunities and enhances the users' ability to value such opportunities. Knowledge in common is necessary for learning to occur between two exchange partners; nevertheless, some diversity of knowledge is required for transfer of new knowledge to occur. Indeed, exposure to many different external contacts is essential to learning in a new competitive environment. Exposure to a variety of other research centres enhances the ability of the users to assess and value the knowledge available from CERN. This diversity of contacts is key to increasing the breadth, depth and speed of users' learning: exposure to a diversity of external contacts increases the users' learning by doing, increasing new knowledge integration skills and, thereby, the speed and depth of subsequent technological learning.

This leads to research sub-question 3c: *if the amount of CERN network ties provided by CERN is higher, will users' knowledge acquisition from those connections be greater?*

6.1.4 Knowledge acquisition and competitive advantage

The first set of research sub-questions links social capital with knowledge acquisition. Knowledge acquisition is related to invention development and technological distinctiveness, which are competitive advantage outcomes. Implicitly, this discussion suggests that social capital affects competitive advantage outcomes via its effects on knowledge acquisition. While social capital provides basic elements for achieving benefits, the organizational learning process converts social capital into tangible benefits. This means that knowledge acquisition mediates the relationships between social capital constructs and competitive advantage outcomes.

Organizations learn and innovate through knowledge communication and combination. Establishing novel associations between existing domains of knowledge creates new combinations, and effective communication enhances the potential for creating such associations. Knowledge acquisition via relationships contributes to invention development in high-technology sectors, because invention development requires the integration and combination of specialized knowledge inputs from many different areas of technology. Successful invention development requires input of relevant complementary knowledge (e.g., market, manufacturing and design knowledge), so that, even if technically possible, strictly in-house development of such complementary knowledge is often not economically feasible. Thus, knowledge acquisition can increase invention development in two ways: by enhancing the breadth and depth of relation-specific knowledge available to the user, thereby increasing the potential for new innovative combinations; and by increasing the willingness of the user to develop inventions for CERN.

Knowledge diversity, increasing the depth, breadth, and speed of learning, leads to a greater number of product introductions. Technological learning provides a foundation for developing organizational routines that reinforce existing core competences and facilitate the building of new ones; these, in turn, enhance value creation and venture performance. Finally, external relation-specific knowledge acquisition enhances product development by increasing the willingness to develop inventions.

This leads to research sub-question 4a: ***if users' knowledge acquisition increases from the relationship between CERN and its users, will the quantity of inventions developed by the users as a result of that relationship also increase?***

Greater depth of knowledge, especially knowledge acquired via interaction with CERN, enhances the ability to conceive and realize significant product differentiation. Richer and more varied knowledge can also be used to upgrade products, to increase user specialization and to understand competing and complementary technologies, thus enhancing the distinctiveness of the focal technology. Learning in interorganizational relationships is an important means of acquiring technological competences.

This leads to research sub-question 4b: ***if users' knowledge acquisition is greater because of the relationship between CERN and its users, will the technology developed by users as a result of that relationship be more distinctive?***

6.1.5 General view

Only individuals, and not an organization as such, create and expand knowledge, through social interaction between tacit and explicit knowledge. It is essential for an organization to support and stimulate the knowledge-creating activities of individuals or to provide the appropriate contexts for them. It is thanks to a continuous and dynamic interaction between tacit and explicit knowledge that innovation emerges. The nature of knowledge represented by the individuals' value system is a fundamental to explaining how innovation is realized. CERN is a research organization in which scientific knowledge is acquired. Users are in danger of losing creativity and innovativeness if they become too dependent on CERN, which aids knowledge acquisition by providing and improving introductions to other research institutions. This dynamic inside and outside interaction facilitates the transformation of personal knowledge into organizational knowledge, which can fuel innovations, leading to competitive advantage via enhanced technological distinctiveness and invention development.

Thus, the main research sub-question is: *is the way CERN users appreciate their own acquired knowledge a measure of the success of the social process in advancing the scientific and technological processes to create new knowledge and ultimately innovation?*

6.2 Analysis of responses

This section is devoted to the analysis of the responses to each question of the questionnaire received from both Finnish and Italian samples with respect to the process structure of CERN knowledge creation, acquisition and transfer model.

Question 1 refers to *"your most important contribution from a technical or scientific point of view".*

This question invites the respondents to quantify their most important scientific and technical contributions whilst at CERN on a scale from 1 (satisfactory) to 5 (very good) in various domains of physics, engineering and administration (Figs. 6.1 and 6.2). The domains of physics are: research, theoretical physics, applied physics, electronics, software & computing, and R&D project. The domains in engineering are: vacuum, superconductivity & cryogenics, accelerator, material science, technical support, mechanics, and electronics. The domains of administration are: administrative support, purchasing, and finance & administration. The general formulation of the question refers to the scientific and technological process. Physics and engineering correspond to the scientific process and the technological process respectively. Administration is extended to the social process. The Finns' and Italians' contribution to physics (P), engineering (E) and administration (A) are shown in Table 6.1.

Table 6.1: Question 1: Your most important contribution from a technical or scientific point of view. Number of respondents who filled in one field: P, E, A; two fields: P+E, P+A, E+A; or three fields: P+E+A.

Users	Field	P	E	A	P+E	P+A	E+A	P+E+A	Total
Finns	**Physics**	15			6	0		9	30
	Engineering		7		6		1	9	23
	Administration			3		0	1	9	13
Italians	**Physics**	30			10	0		6	46
	Engineering		5				0	6	21
	Administration			0	10	0	0	6	6

Note: P = Physicists, E = Engineers, A = Administrators

Figures 6.1 and 6.2 show that, in the field of physics, the majority of Finns and Italians gave the maximum rating (5) to software & computing and research respectively. In the field of engineering, they gave maximum rating to technical support (Finns) and material sciences (Italians). In the administration field, two Finns and one Italian evaluated all three domains with the maximum rating: administrative support, purchasing and finance & administration.

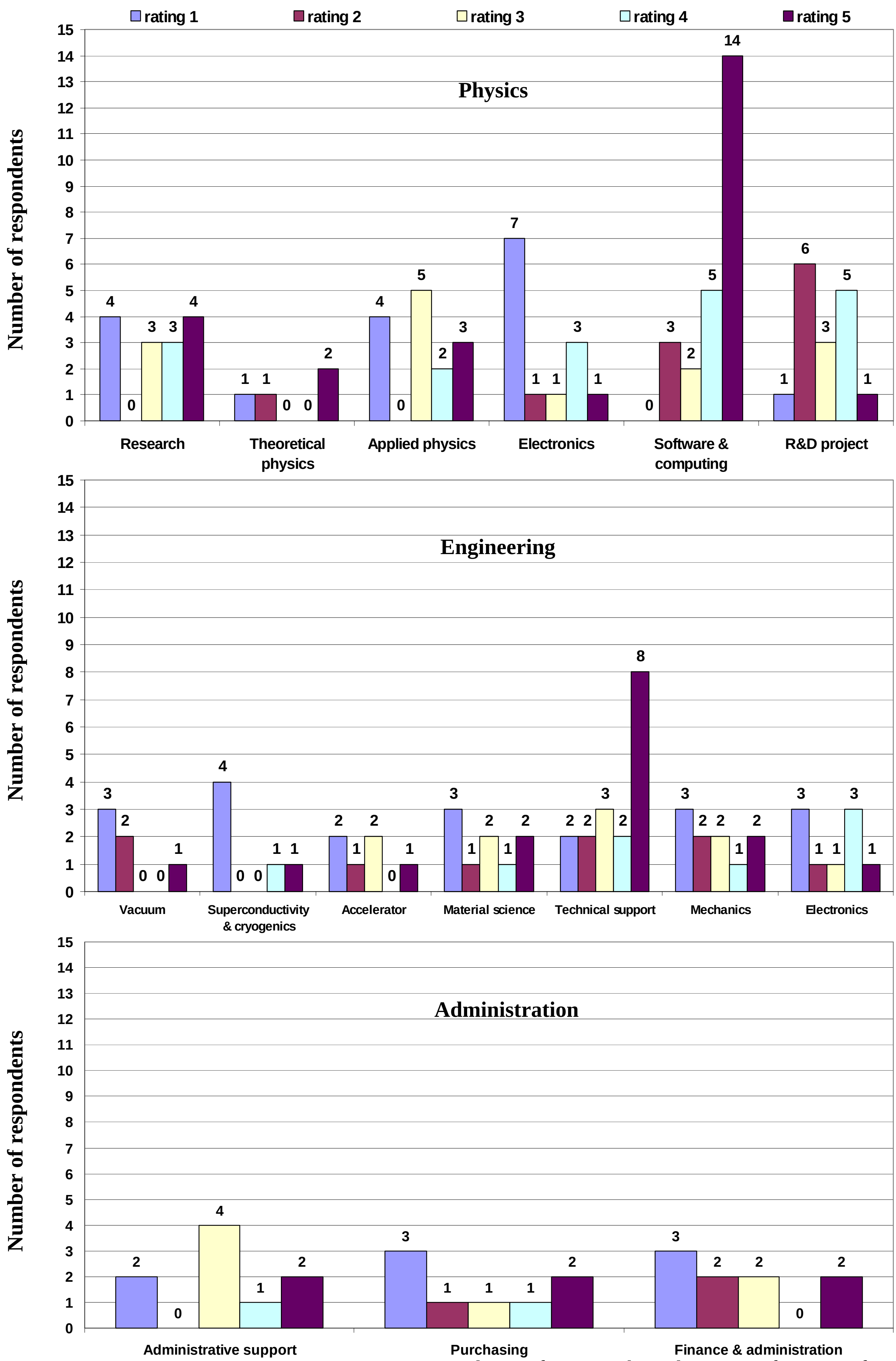


Fig. 6.1: Question 1 Your most important contribution from a technical or scientific point of view. Number of entries: 41 Finns (not including 6 no answers).

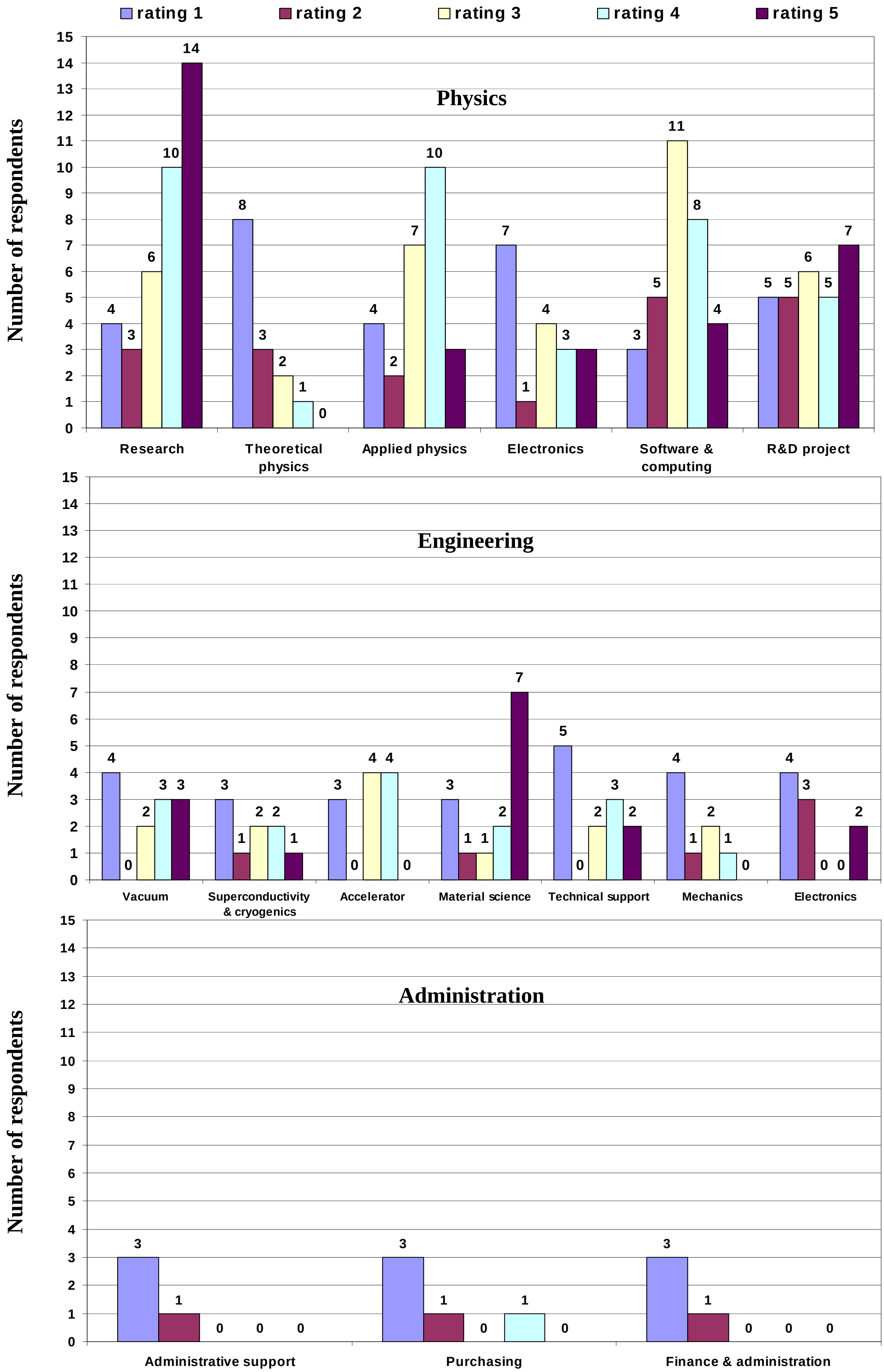


Fig. 6.2: Question 1 Your most important contribution from a technical or scientific point of view. Number of entries: 51 Italians.

The average contribution of Finnish and Italian men (M) and women (F) to subjects of Physics (P), Engineering (E) and Administration (A) are obtained from the following formulas using the values in Tables 6.2a and 6.2b and are shown in Table 6.3a:

$$\langle M \rangle_P = \frac{1}{m}\sum_{j=1}^{m}\left[\frac{1}{n_{P_j}}\sum_{i=1}^{6} x_{P_{i,j}}\right], \qquad \langle F \rangle_P = \frac{1}{f}\sum_{j=1}^{f}\left[\frac{1}{n_{P_j}}\sum_{i=1}^{6} x_{P_{i,j}}\right],$$

$$\langle M \rangle_E = \frac{1}{m}\sum_{j=1}^{m}\left[\frac{1}{n_{E_j}}\sum_{i=1}^{7} x_{E_{i,j}}\right], \qquad \langle F \rangle_E = \frac{1}{f}\sum_{j=1}^{f}\left[\frac{1}{n_{E_j}}\sum_{i=1}^{7} x_{E_{i,j}}\right],$$

$$\langle M \rangle_A = \frac{1}{m}\sum_{j=1}^{m}\left[\frac{1}{n_{A_j}}\sum_{i=1}^{3} x_{A_{i,j}}\right], \qquad \langle F \rangle_A = \frac{1}{f}\sum_{j=1}^{f}\left[\frac{1}{n_{A_j}}\sum_{i=1}^{3} x_{A_{i,j}}\right].$$

The average contribution of physicists (Ph), engineers (En) and administrators (Ad) to subjects of physics (P), engineering (E) and administration (A) are obtained from the following formulas using the values in Tables 6.2a and 6.2b and are shown in Table 6.3b:

$$\langle Ph \rangle_P = \frac{1}{p}\sum_{j=1}^{p}\left[\frac{1}{n_{p_j}}\sum_{i=1}^{6} x_{P_{i,j}}\right], \qquad \langle En \rangle_P = \frac{1}{e}\sum_{j=1}^{e}\left[\frac{1}{n_{p_j}}\sum_{i=1}^{6} x_{P_{i,j}}\right], \qquad \langle Ad \rangle_A = \frac{1}{a}\sum_{j=1}^{a}\left[\frac{1}{n_{P_j}}\sum_{i=1}^{6} x_{P_{i,j}}\right],$$

$$\langle Ph \rangle_E = \frac{1}{p}\sum_{j=1}^{p}\left[\frac{1}{n_{E_j}}\sum_{i=1}^{7} x_{E_{i,j}}\right], \qquad \langle En \rangle_E = \frac{1}{e}\sum_{j=1}^{e}\left[\frac{1}{n_{E_j}}\sum_{i=1}^{7} x_{E_{i,j}}\right], \qquad \langle Ad \rangle_E = \frac{1}{a}\sum_{j=1}^{a}\left[\frac{1}{n_{E_j}}\sum_{i=1}^{7} x_{E_{i,j}}\right],$$

$$\langle Ph \rangle_A = \frac{1}{p}\sum_{j=1}^{p}\left[\frac{1}{n_{A_j}}\sum_{i=1}^{3} x_{A_{i,j}}\right], \qquad \langle En \rangle_A = \frac{1}{e}\sum_{j=1}^{e}\left[\frac{1}{n_{A_j}}\sum_{i=1}^{3} x_{A_{i,j}}\right], \qquad \langle Ad \rangle_A = \frac{1}{a}\sum_{j=1}^{a}\left[\frac{1}{n_{A_j}}\sum_{i=1}^{3} x_{A_{i,j}}\right].$$

Where:

j = number of persons, m =number of men, f = number of women, p = number of physicists, e = number of engineers, a = number of administrators, i = number of domains within the fields, and n = number of non-zero values x.

Table 6.2a: Question 1: Your most important contribution from a technical or scientific point of view. Average contribution to physics, engineering and administration by Finns.

Quantity	Individual contributions to sum	Result
$\langle M \rangle_P$	(29/6)+(5/2)+(6/2)+(9/3)+(9/2)+(5/1)+(4/2)+(3/1)+(9/2)+(13/5)+(8/2)+(12/3)+(17/6)+(16/6)+(17/6)+4*(5/1)+ +(8/2)+(4/1)+(10/6)+(12/6)+(14/6)+(3/2)+2*(5/1)+7*0=	2.85
$\langle M \rangle_E$	(12/7)+(5/1)+(3/1)+(2/1)+(8/2)+(5/1)+(2/1)+(12/3)+(6/3)+(5/3)+(4/1)+(9/2)+(11/7)+(7/7)+(2/1)+(17/7)+(17/5)+17*0=	1.48
$\langle M \rangle_A$	(6/3)+(1/1)+(4/1)+(3/3)+(10/3)+(3/3)+(10/3)+(8/3)+26*0=	0.69
$\langle F \rangle_P$	(14/6)+(20/6)+(11/3)+4*0=	1.33
$\langle F \rangle_E$	(5/1)+(5/1)+(35/7)+(5/1)+3*0=	2.86
$\langle F \rangle_A$	(15/3)+(8/2)+5*0=	1.29
$\langle Ph \rangle_P$	(29/6)+(5/2)+(6/2)+(9/3)+(9/2)+(5/1)+(4/2)+(3/1)+(9/2)+(13/5)+(8/2)+(12/3)+(17/6)+(16/6)+(14/4)+(11/3)+(17/6)+4*(5/1)=	3.68
$\langle Ph \rangle_E$	(12/7)+(5/1)+(3/1)+(2/1)+(8/2)+(5/1)+(2/1)+14*0=	1.08
$\langle Ph \rangle_A$	(6/3)+(1/1)+19*0=	0.14
$\langle En \rangle_P$	(8/2)+(4/1)+(20/6)+(10/6)+(12/6)+(14/6)+(3/2)+2*(5/1)+8*0=	1.69
$\langle En \rangle_E$	(5/1)+(12/3)+(6/3)+(5/3)+(4/1)+(5/1)+(9/2)+(35/7)+(11/7)+(7/7)+(2/1)+(17/7)+(5/1)+(17/5)+3*0 =	2.79
$\langle En \rangle_A$	(4/1)+(15/3)+(3/3)+(10/3)+(3/3)+(10/3)+11*0=	1.04
$\langle Ad \rangle_P$	3*0=	0
$\langle Ad \rangle_E$	3*0=	0
$\langle Ad \rangle_A$	(8/3)+(8/2)+(5/1) =	3.89

Table 6.2b: Question 1:Your most important contribution from a technical or scientific point of view. Average contribution to physics, engineering and administration by Italians.

Quantity	Individual contributions to sum	Result
$\langle M \rangle_P$	(10/3)+(5/2)+(24/5)+(14/3)+(17/6)+(18/6)+(9/3)+(3/1)+(13/4)+(12/4)+(26/6)+(9/2)+(10/2)+(8/2)+(12/3)+(17/6)+(4/2)+(9/2)+ +(14/6)+(9/6)+(4/1)+(9/2)+(6/2)+(18/6)+(11/6)+(2/1)+(2/1)+(5/1)+(6/2)+(5/1)+(8/2)+(13/5)+(6/6)+(12/3)+(11/3)+(5/1)+0=	3.05
$\langle M \rangle_E$	(9/4)+(16/4)+(3/1)+(7/2)+(10/2)+(10/7)+(7/7)+(19/7)+(23/7)+(3/1)+(22/7)+(10/2)+(9/2)+(4/1)+(17/7)+(18/5)+(17/7)+(3/1)+(4/4)+21*0=	1.53
$\langle M \rangle_A$	(3/3)+(3/3)+(8/3)+(3/3)+(3/3)+(2/1)+34*0=	0.22
$\langle F \rangle_P$	(15/5)+(8/2)+(9/3)+(15/5)+(12/4)+(7/2)+(17/5)+(3/2)+(2/1)+(14/6)+0=	2.61
$\langle F \rangle_E$	(11/3)+10*0=	0.33
$\langle F \rangle_A$	11*0=	0
$\langle Ph \rangle_P$	(13/3)+(5/2)+(24/6)+(15/5)+(8/3)+(14/3)+(9/3)+(17/6)+(15/5)+(16/4)+(9/3)+(3/1)+(13/4)+(7/2)+(12/4)+(26/6)+(9/2)+(10/2)+(8/2)+ +(12/3)+(17/5)+(17/6)+(3/2)+(4/2)+(14/6)+(9/6)+(2/1)+(9/2)+(18/6)+(14/6)+(2/1)+(2/1)+(5/1)+(8/2)+(12/3)+(11/3)+(5/1)=	3.26
$\langle Ph \rangle_E$	(3/1)+(7/2)+(10/7)+(7/7)+(3/1)+(4/1)+31*0=	0.43
$\langle Ph \rangle_A$	(3/3)+(3/3)+(2/1)+34*0=	0.11
$\langle En \rangle_P$	(18/6)+(9/2)+(7/2)+(6/2)+(11/6)+(5/1)+(6/2)+(13/5)+(6/6)=5*0=	1.96
$\langle En \rangle_E$	(9/4)+(11/3)+(16/4)+(10/2)+(19/7)+(23/7)+(3/1)+(22/7)+(10/2)+(9/2)+(4/1)+(17/7)+(18/5)+(17/7)=	3.39
$\langle En \rangle_A$	(8/3)+(3/3)+(3/3)+11*0=	0.33

Table 6.3a: Question 1: Your most important contribution from a technical or scientific point of view. Average contribution to physics, engineering and administration.

Fields	Finns		Italians	
	Men (n = 34)	**Women** (n = 7)	**Men** (n = 40)	**Women** (n = 11)
Physics	2.85	1.33	3.05	2.61
Engineering	1.48	2.86	1.53	0.33
Administration	0.69	1.29	0.22	0

Table 6.3b: Question 1: Your most important contribution from a technical or scientific point of view. Average contribution to physics, engineering and administration.

Fields	Finns			Italians	
	Physicists (n = 21)	**Engineers** (n = 17)	**Administrators** (n = 3)	**Physicists** (n = 37)	**Engineers** (n = 14)
Physics	3.68	1.69	0	3.26	1.96
Engineering	1.08	2.79	0	0.43	3.39
Administration	0.14	1.04	3.89	0.11	0.33

Referring to Section 4.3.4, the results indicate that Finnish women show more awareness of the role of the scientific and technological processes within engineering than men (average: f = 2.86 and m = 1.48 respectively), whereas the opposite is true within physics (average: f = 1.33, m = 2.85). Finnish administrators demonstrated more of a contribution to administration (average = 3.89) than physicists did to physics (average = 2.79) or engineers to engineering (average = 3.68). Italian men and women show more awareness of the role of the scientific and technological processes in physics (average: m = 3.05, f = 2.61) than in engineering (average: m = 1.53, f = 0.33). Finnish physicists are more aware of their contribution to physics (average: Finns = 3.68, Italians = 3.26) than Italian physicists; the opposite is true for the Italian and Finnish engineers (average: Italians = 3.26, Finns = 1.96).

Questions 2 and 3 refer to acquired knowledge and acquired knowledge per topic. The general formulation of questions 2 and 3 refers to connections between the scientific process, technological process and social process (Section 4.3.4). In question 3 users have to specify their acquired skills in a list of fields, including theoretical physics, experimental physics, computing, technical fields, financial aspects, languages, communication, science communication and managerial aspects.

The majority of respondents interpreted questions 2 and 3 having basically the same meaning. Ninety-five per cent of the respondents replied to question 3 by referring to question 2. This is why the author has chosen to show only the results from the analysis of answers to question 3 (Table 6.4). Physicists and engineers in both samples, Finnish and Italian, have acquired skills in different domains. They have acquired knowledge especially in experimental physics, which involves scientific and technological processes (Finns: 16 physicists, seven engineers, no administrators; Italians: 25 physicists, five engineers); computing and technical fields, related only to the technical process (Finnish physicists: 11 computing + seven technical fields, engineers: three computing + six technical fields, no administrators; Italian physicists: 25 computing + 15 technical fields, engineers: five computing + 11 technical fields), communication and science communication, connected to the social process (Finnish physicists: five communication + six science communication, engineers: three communication + one science communication, administrators: one communication + one science communication; Italian physicists: 25 communication + 13 science communication, engineers: five communication + three science communication). Italian physicists declared they have acquired knowledge in financial and managerial aspects, also belonging to the social process (physicists: eight financial aspects + 18 managerial aspects, engineers: no financial aspects + two managerial aspects), which, in the Finnish sample have been learned mostly by engineers (physicists: one financial aspects + five managerial aspects, engineers: four financial aspects + eight managerial aspects, administrators: one financial aspects + two managerial aspects).

Referring to Section 4.3.4, a possible interpretation of the results is that respondents acquire skills belonging to all three processes; in particular, Italian physicists, Finnish engineers and administrators developed social skills.

Table 6.4: Question 3: Learning acquisition per topic.

Fields	**Finns** (n = 39, not including 9 no answers)			**Italians** (n = 49, not including 2 no answers)	
	Physicists	**Engineers**	**Administrators**	**Physicists**	**Engineers**
Theoretical physics	5	0	0	12	0
Experimental physics	11	3	0	31	7
Computing	16	7	0	25	5
Technical fields	7	6	0	15	11
Financial aspects	1	4	1	8	0
Languages	5	4	0	23	6
Communication	5	3	1	25	5
Science communication	6	1	1	13	3
Managerial aspects	5	8	2	18	2

Question 4 asks to "list the fields of interest developed or topics studied by interacting with colleagues at CERN or outside CERN". Questions 5 and 6 are "which one of the answers to question 4 have you put into practice since your stay

at CERN?" And " which one of the answers to question 5 has proved the most useful?" Question 5 and question 6 refer together with question 4 to the social process. In particular, in the general formulation of question 4, terms such as 'fields of interest' and 'topics studied' are directly connected to the scientific and technological processes, and expressions such as 'interacting with colleagues', are linked to the social process (Section 4.3.4). In questions 5 and 6, 98% of respondents referred to the answers given in question 4. This is why the author decided to illustrate only results from question 4 (Table 6.5). Thanks to interaction with colleagues, some of the samples developed interests outside their direct work activity more specifically 38% of the Finnish and 15% of the Italian sample. This could be an indication of the role of the social process in scientific and technological knowledge creation, acquisition and transfer through the interactions among colleagues inside and outside the CERN working environment.

Table 6.5: Question 4: List of interests developed by interacting with colleagues.

Interest	**Finns** (n = 47)	**Italians** (n = 51)
Related to field of activity	56%	75%
Not related to field of activity	38%	15%
Both	6%	10%

Question 7 refers to the "*impact of working in an international environment*".

Table 6.6 shows the results obtained from the analysis of question 7. In this question, Finns and Italians illustrate the influences of working in an international environment from both the professional and personal points of view. This should give an impression of the importance of having different contacts in improving knowledge acquisition. Finnish physicists and engineers, give a very similar evaluation of the fields, discussion with colleagues, living abroad and cultural broadening aspects, which all relate to the significance of the social process for the scientific and technological processes. Finnish administrators indicated the importance of living abroad and planning, which refer to the social process and involves elements of the other two processes. Italian physicists give most importance to discussion with colleagues, scientific point of view, cultural broadening aspects and living abroad, which is directly connected with the scientific process. Italian engineers highlight the importance of planning. Referring to Section 4.3.4, both Finnish and Italian samples show awareness of the three processes, with particular respect to the mediating role of the social process, in the knowledge creation, acquisition and transfer model.

Table 6.6: Question 7: Impact of working in an international environment.

Fields	Finns (n = 45, not including 2 no answers)			Italians (n = 50, not including 1 no answer)	
	Physicists	Engineers	Administrators	Physicists	Engineers
Discussion with colleagues	14	10	1	28	7
Living abroad	14	12	2	17	7
Scientific point of view	13	5	1	28	9
Cultural broadening aspects	14	13	1	20	9
Training	3	4	0	10	3
Planning	0	2	2	8	13

Question 8 refers to the "*impact of training*". This question involves one type of social process: interaction between the trainer and the trainee. Its fields refer to the scientific and the technological processes within the social process between different hierarchical levels. In both Finnish and Italian samples, physicists participated mainly in seminars and engineers in the CERN Education Service training, which was also the only type of training attended by administrators (Table 6.7). By referring to Section 4.3.4, these results could give an indication of how respondents recognize the role of the social process among people from different hierarchical levels in seminars and training participation.

Table 6.7: Question 8: Impact of training.

Fields	Finns: (n = 32, not including 1 no answers)			Italians (n = 40, not including 11 no answers)	
	Physicists	Engineers	Administrators	Physicists	Engineers
Summer student lecture	9	4	0	8	0
Seminars	10	6	0	26	5
Academic training	5	5	0	16	4
CERN Education Service training	5	7	2	10	6

Question 9 is "*which lectures have impressed you most?*" Allowing the sample to specify which lecture attended for skill acquisition or out of general interest impressed them most meant that respondents could elaborate their answer to question 8. Most underlined that the lectures were very useful for keeping them up to date on recent results and for learning about subjects not directly related to their field. Some noted that these events mean CERN is a good case for innovation and transfer of technologies. Some considered the opportunity to ask questions the most important feature, because in this way new collaborations could start. Respondents consider the following points the most important:

- Seminars from Nobel Prize winners.
- Lectures on accelerator theory, experimental and theoretical physics, quantum field theory, general relativity, standard model, super symmetry and Higgs search.
- Courses on computing, technologies, safety in research projects, introduction to management theory, communication and language.
- Accelerators schools.

According to Section 4.3.4, these points perhaps reinforce respondents' awareness of the mediating role of the social process between the scientific and the technological processes.

Question 10 is *"which skills did you expect to develop or acquire but were unable to?"* Question 10 invites respondents to criticize knowledge acquisition and refers to the role of the three processes: the role of the scientific process in Education, the role of the technological process in technical skills and the role of the social process in education, management and communication.

The results show that Italians are less satisfied than Finns (Table 6.8). Physicists from both Finnish and Italian samples were particularly critical of communication and management, as were Finnish engineers, but not Italian engineers, who were critical only of management. Administrators expected to acquire knowledge in communication but were unable to. The tendency to centralize important decisions was the usual criticisms of management. By referring to Section 4.3.4, by being critical of knowledge acquisition, respondents demonstrated their appreciation of the role of the social process in communication and management.

Table 6.8: Question 10: Which skill did you expect to develop or acquire but were unable to?

Fields	**Finns** (n = 15, not including 32 no answers)			**Italians** (n = 25, not including 26 no answers)	
	Physicists	**Engineers**	**Administrators**	**Physicists**	**Engineers**
Education	1	2	1	7	1
Technical skill	1	3	0	4	1
Management	2	2	1	8	1
Communication	5	4	2	8	0

Question 11 is *“have the multicultural aspects of CERN influenced your career development?”* This question refers to the social process. The results obtained from analysis of the question are shown in Table 6.9.

Table 6.9: Question 11:Have the multicultural aspects of CERN influenced your career development?

Users	**Finns** (n = 39, no answers = 8)		**Italians** (n = 45, no answers = 2)	
	Yes	**No**	**Yes**	**No**
Physicists	14	4	22	11
Engineers	13	5	10	2
Administrators	2	1		

The respondents could elaborate their ‘yes’ or ‘no’ answer in an open section of the question allowing them to specify why they considered their experience at CERN to be positive. The following points illustrate what have been observed to be the most important positive effect of working at the Organization:

- Interaction with people with different mentalities (12 Finns ‘F’, 12 Italians ‘I’)
- Self-confidence because of working in a foreign country (seven F, five I)
- More focus on foreign market (one F)
- Meeting talented individuals (two F)
- Getting many ideas (one F)
- Carrying out not only research but also different types of work (one I)
- Opportunity to create enterprises with people from different environments (one I)
- Acquisition of wider perspectives (one F, two I)
- Approach to practical problems (one I)
- Gaining a good reputation in the scientific and industrial environment (two F, two I)
- Managerial experience (one F)

‘No’ answers were not explained, except in a few cases by the following statements:

- Moved back to home country (one I)
- Too short visit (one F, two I)
- Still student (two F)

- Not the first experience in a multicultural environment (two F, one I)
- All the same nationality in the working group (two F)

By referring to Section 4.3.4, it can be concluded that the multicultural aspects of CERN had a positive influence on users' career development, showing the importance of the social process in the knowledge creation, acquisition and transfer model.

Questions 12 and 13 are *"which fields or subjects did not meet your expectations?"* And *"what did you consider negative about CERN?"* These open-type questions refer to users' expectations and their non-fulfilment by CERN. In the general formulation, the words 'fields' and 'subjects' are directly connected with the scientific and technological processes. In answering question 12, 96% of respondents referred to responses to question 10. This is why the author chose not to illustrate the results from this question. In the answers to question 13 users identify the reasons of their dissatisfaction as the excess of bureaucracy in CERN management, business and administration, and CERN's tendency in recent years to steer research work in an overly technical and mechanical direction. In addition, several students from both the Finnish and Italian samples complained of not having been adequately supervised, especially at the beginning of their CERN experience. Some users suggested that giving more consideration to the industrial approach would improve management and encouraging meetings between people from different experiments in order to share experiences would improve communication. With reference to Section 4.3.4, it is possible to see in these criticisms, as in the analysis of the previous questions (10, 11 and 12), how respondents appreciate the role of the social process.

Questions 14 and 15 are *"what was the most important aspect for your personal development?"* And *"which technology acquired or skill improved while at CERN has had the greatest impact on your career?"*

The general formulation of question 14 is related to all three processes (scientific, technological and social). The general formulation of question 15 is related to the technological process, but does not exclude scientific and social skills, which are features of the scientific and social processes. For the analysis, the answers have been itemized, and the statements relevant to this study have been selected and classified into six categories, with the following keyword definitions: 'being independent', 'work in a multicultural environment', 'dealing with a high-level research centre', 'living abroad', 'communicating with people and managing work', and 'not relevant' (question 14); and 'technology related to the work activity', 'knowledge related to the work activity', 'information technology and electronics', 'technology process: from conception to spin-offs, 'project and personnel management', and 'not applicable' (question 15).

Question 14

1. Being independent (three statements: 'self esteem', 'freedom to choose' and 'autonomy')
2. Work in a multicultural environment (two statements: 'meeting different people' and 'working in an international place')
3. Dealing with a high-level research centre (1 statement: 'meeting high-qualified or senior physicists')
4. Living abroad (two statements: 'learning languages' and 'appreciating the culture')
5. Communicating with people and managing work (two statements: 'learning projects' work' and 'communicating with team colleagues')
6. Not relevant.

Question 15

1. Technology related to the work activity (one statement: 'technological knowledge in the activity field')
2. Knowledge related to the work activity (one statement: 'scientific skill in the activity field')
3. Information technology and electronics (four statements: 'software', 'hardware', 'computing" and 'programming')
4. Technology process: from conceptions to spin-offs (three statements: 'idea', 'application' and 'transfer of technology')
5. Project and personnel management (two statements: 'organizing work' and 'communicating with people')
6. Not applicable

The results of the analysis of these two open-type questions are shown in Tables 6.10 and 6.11 respectively. In question 14 respondents from both the Finnish and the Italian sample give most importance to working in a multicultural environment (15 Finns, 27 Italians) and dealing with a high-level research centre (16 Finns, 19 Italians). On the basis of these answers a possible interpretation is that users are able to evaluate their own personal development and appreciate their level in the hierarchy. For question 15, information technology and electronics was the field in which the majority of Finnish and Italian users underlined the greatest technological distinctiveness. Clear differences between the two samples are observed in their answers relating to technology related to the work activity: six Finns and 18 Italians believed technology acquired related to their activity had the greatest impact on their career.

Table 6.10: Question 14: What was most important for your personal development?

Fields	**Finns** (n = 33, not including 14 no answers)	**Italians** (n = 48, not including 3 no answers)
Being independent	6	4
Living abroad	9	7
Working in a multicultural environment	15	27
Dealing with a high level research centre	16	19
Communicating with people and managing work	5	11
Not relevant	0	1

Table 6.11: Question 15: Technology acquired or skill improved while at CERN which had the greatest impact on career.

Fields	**Finns** (n = 34, not including 13 no answers)	**Italians** (n = 44, not including 7 no answers)
Technology related to the work activity	6	18
Information Technology and Electronics	15	19
Technology process: from conception to spin-offs	2	2
Knowledge related to the work activity	7	7
Project and Personnel management	4	2
Not applicable	4	7

According to Section 4.3.4, the results of both of these questions could be interpreted as demonstrating the importance the users accord to all three processes in the knowledge creation, acquisition and transfer model, and particularly to the scientific and technological skills reported in question 15.

Question 16 refers to *"participation in R&D projects"* and question 17 is *"was there any technological return or application you are aware of?"* Tables 6.12 and 6.13 show the results obtained from the analysis of the answers to these questions, which aim at assessing users' participation in R&D activities and their awareness of the notion of technology transfer. The general formulation of question 16 refers to both the scientific and technological processes and the general formulation of question 17 refers only to the technological process, while the participation in projects belongs to the social process.

Table 6.12: Question 16: Participation in R&D projects.

Users	**Finns** (n = 37, no answers = 10)		**Italians** (n = 48, no answers = 3)	
	Yes	**No**	**Yes**	**No**
Physicists	13	8	18	16
Engineers	10	4	13	1
Administrators	2	0		

Table 6.13: Question 17: Possible technological returns or applications.

Users	**Finns** (n = 34, no answers = 13)		**Italians** (n = 45, no answers = 6)	
	Yes	**No**	**Yes**	**No**
Physicists	12	9	8	23
Engineers	8	4	9	5
Administrators	0	1		

According to the answers to question 16, the majority of physicists (13 Finns, 18 Italians) and engineers (10 Finns, 13 Italians) in both samples are involved in R&D projects. In answer to question 17, 13 Finns (9 physicists and four engineers) and 28 Italians (23 physicists and five engineers), declared not to have had any technological returns or applications. According to Section 4.3.4, in being involved in R&D projects respondents are indicating their role in the social process, even if they do not recognize the importance of this process in technology transfer.

Question 18 refers to *"positive or negative experience of meetings".* The general formulation of this question is related to the social process. In this question respondents are invited to evaluate the impact of meetings held at CERN on learning. The meetings are divided into the four categories of general, collaboration, divisional or group, and project meetings. All the meetings were evaluated with respect to illustration of subjects, definition of problems, work organization, management and time schedule. The answers obtained from the Finns and Italians show the active and critical participation of respondents in meetings (Figs. 6.3 and 6.4).

The Finns overall were positive towards the project meetings regarding all subjects except time schedule, which is related to the social process. A similar tendency can be seen in the other types of meetings. Management and work organization, which are connected to the social process, have been generally the most criticized aspects of meetings, whereas illustration of subjects and definition of problems, related to the scientific process, are overall considered positively by respondents. The positive experiences are concentrated in those subjects that have a direct supportive relation to the scientific and technological processes and the experiences become more negative the less the subject has to do with science and technology, thus, the Finns seem to be very sensitive towards bureaucracy. Italians evaluated collaboration, divisional or group and project meetings positively in all respects.

Finns

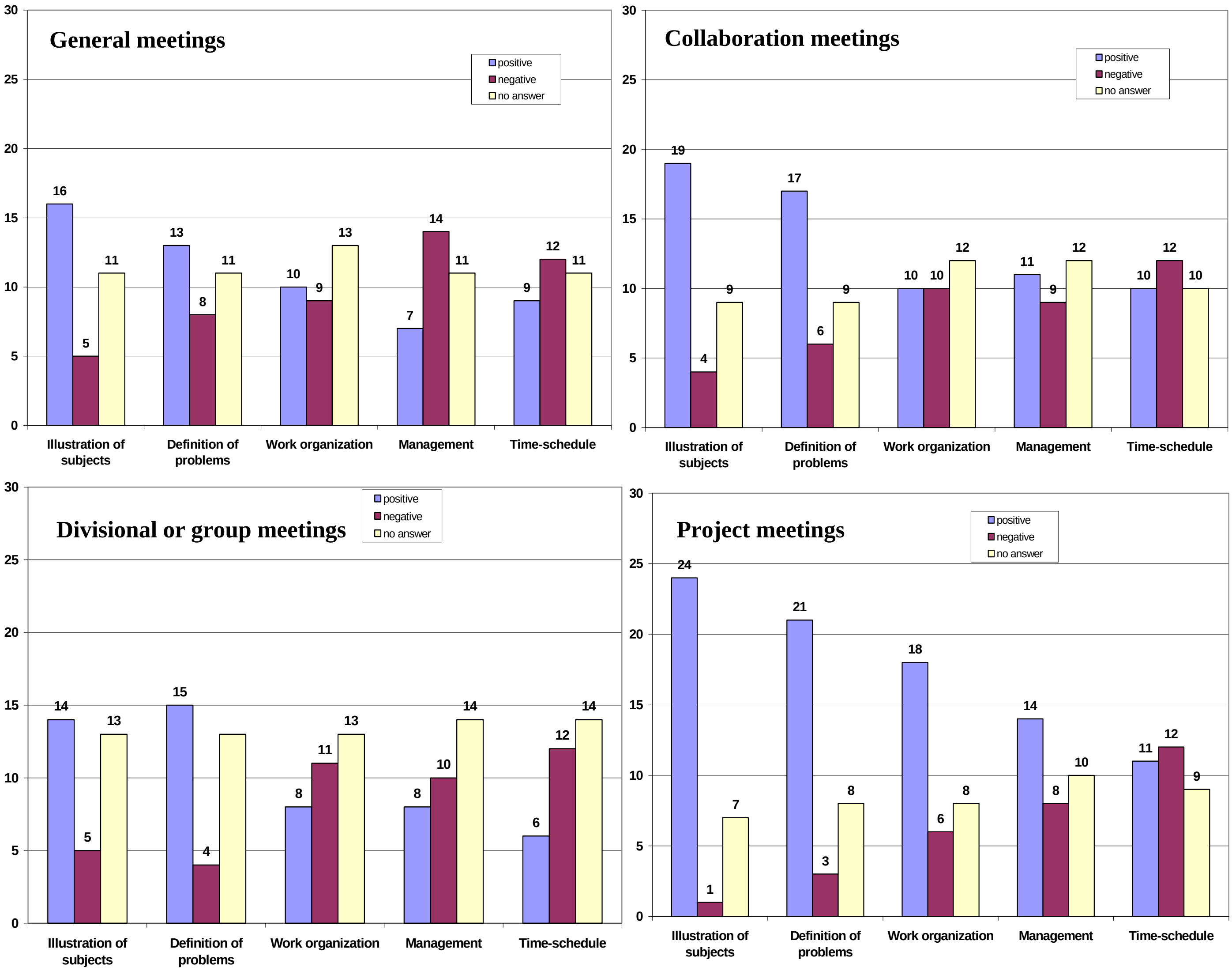


Fig. 6.3: Question 18: Positive or negative experience from general, collaboration, divisional or group and project meetings.
Number of entries: 32 Finns (not including 15 no answers).

With reference to Section 4.3.4, these results could indicate that Finnish and Italian respondents deal more easily with the scientific process than the technological process. Respondents again recognize the importance of the social process even if they are not completely satisfied with some aspects of meetings.

Italians

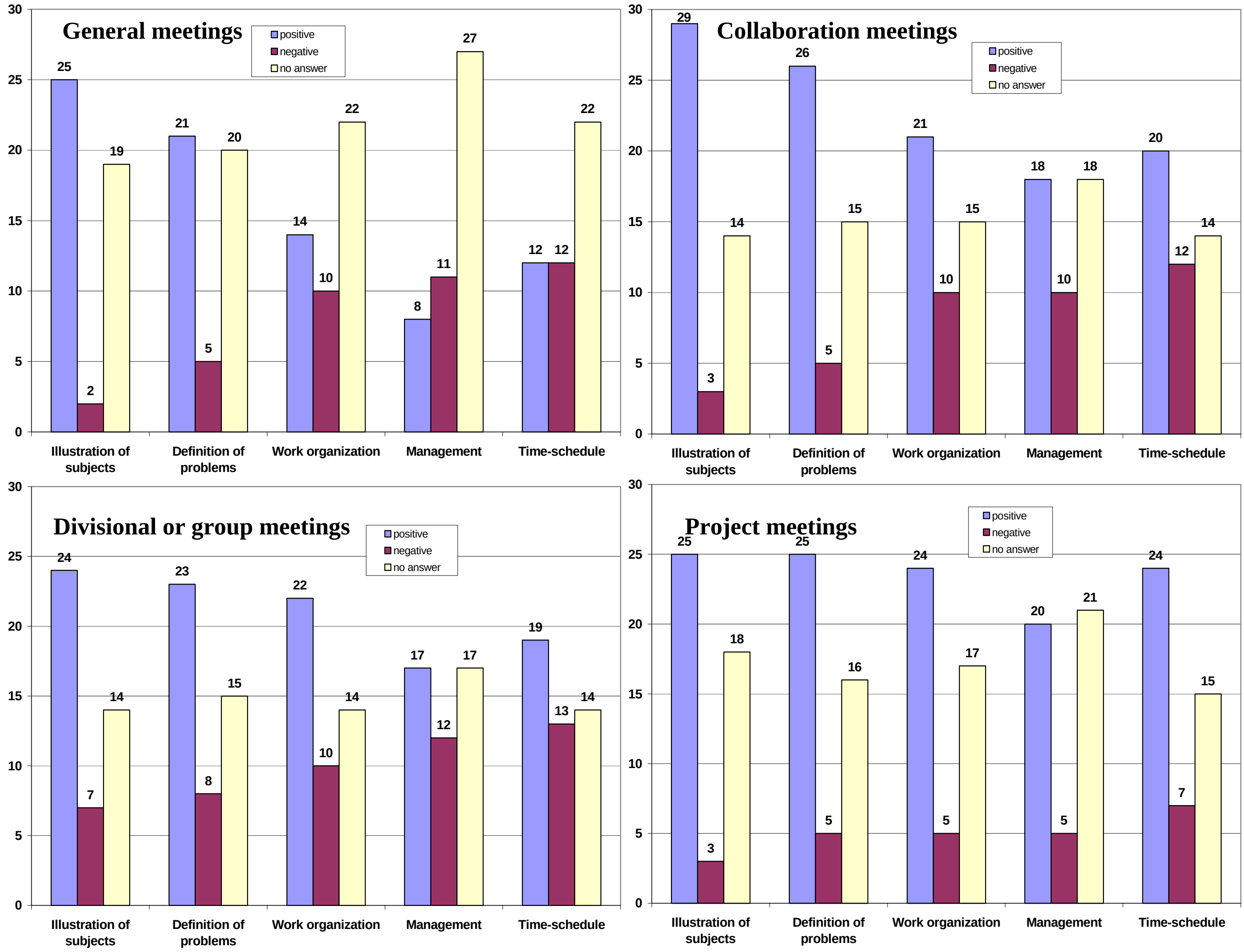


Fig. 6.4: Question 18: Positive or negative experience from general, collaboration, divisional or group and project meetings.
Number of entries: 46 Italians (not including 5 no answers).

Question 19 asks respondents to "*outline the difference between actual work experience and CERN experience from the point of view of the learning process*". In this question respondents are asked to outline the difference between their actual work experience and the CERN experience, by assessing four fields on a scale from 1 (satisfactory) to 5 (very good). The fields managerial and financial considerations belong to the social process and contain elements of the scientific and of the technological process. Scientific stimulation refers to the scientific process, but involving technological components, which are features of the technological process. Finally, multicultural aspects, is connected to the social process.

The average contribution of Finnish physicists (16) and engineers (14), and Italian physicists (33) and engineers (13) to the subjects of managerial, scientific stimulation, financial consideration and multicultural aspects, are shown in Tables 6.14 and 6.15 respectively.

In both samples, Finnish and Italian respondents recognize the importance of the possibility of scientific stimulation (averages: 4.19 and 4.07 for Finnish physicists and engineers, and 4.39 and 4.62 for Italian physicists and engineers respectively) and of dealing with multicultural aspects (averages: 3.94 and 4.07 for Finnish physicists and engineers, and 4.45 and 4.30 for Italian physicists and engineers respectively), greater at CERN than in other work environments. On the other hand, Finnish engineers were not satisfied with CERN financial considerations (averages: 3.14 and 2.64) and CERN managerial aspects (averages: 3.14 and 2.14), and gave preference to actual work experience.

According to Section 4.3.4, these results show that respondents recognize the importance of the scientific process involving technological components, and thus the technological process. Finally, they show the relevance of certain aspects of the social process in mediating the other two processes in the model of knowledge creation, acquisition and transfer.

Table 6.14: Question 19: Outline the difference between actual work and CERN experience for the point of view of the learning process. Average contribution to the actual work experience and to the CERN experience.

Finns (n = 30, not including 16 no answers and 1 answer from administrators)				
Fields	**Physicists** (n = 16)		**Engineers** (n = 14)	
	Work	**CERN**	**Work**	**CERN**
Managerial	2.75	2.25	3.14	2.14
Scientific stimulation	2.88	4.19	2.01	4.07
Financial considerations	2.81	3.06	3.14	2.64
Multicultural aspects	2.31	3.94	2.51	4.07

Note: The average contributions are obtained using the same formulas used for Q_1

Table 6.15: Question 19: Outline the difference between actual work and CERN experience from the point of view of the learning process. Average contribution to the actual work experience and to the CERN experience.

Italians: 46 (not including 5 no answers)				
Fields	**Physicists** (n = 33)		**Engineers** (n = 13)	
	Work	**CERN**	**Work**	**CERN**
Managerial	2.12	2.33	2.38	2.38
Scientific stimulation	2.48	4.39	2.61	4.62
Financial considerations	2.75	3.03	1.76	2.61
Multicultural aspects	2.00	4.45	2.46	4.30

Note: The average contributions are obtained using the same formulas used for Q_1

Question 20 is *"have you obtained a position thanks to the experience acquired at CERN?"* This question does not contain any particular elements of any of the three processes but it should show the influence of working at CERN on the respondent's career. In the Finnish sample, 13 out of 19 physicists and 11 out of 15 engineers answered positively to this question. In the Italian sample, 20 out of 31 physicists and eight of ten engineers obtained a professional position thanks to the CERN experience. The following statements show some important aspects experienced when working at CERN that allowed respondents to get a new job: "such technology experience is rare, also in industry, so this enabled me to obtain job in industry", "moving to a technology start-up that was founded as spin-off of CERN activities" and "my next work place involves the product developed at CERN and its commercialization".

Question 21 probes a sociological point and is addressed in the next Chapter, where the social impact of working in an international research organization is analysed.

6.3 Other observations

It is important to underline the different emphasis in responses to the questionnaire between the younger users, students who come to the Laboratory for the first time, and the older users, researchers who work at CERN over several years. An important part of knowledge acquisition for older users is managing a team, whereas the younger users highlight the importance of communicating science to the public. The importance of management is clear because of the size of CERN's experiments. Communicating science to the public, however, is less expected because this is not really part of CERN's main mandate. Nevertheless, students have acquired valuable communication capabilities by giving guided tours to visitors. Taking into account the impact the World Wide Web (WWW) in today's society, it is understandable that young scientists are eager to communicate their technological achievements to a wider audience [Tho94]. The WWW has created a new mode of communication, not only worldwide, but also between scientists. The technological impact of the Internet has been prevalent at the educational level. The Internet will be the new way to form, inform and educate people. This where technological development will drive media education and communication sciences [Liv00]

The results of the questionnaire provide some evidence of CERN users' awareness of the role of all three processes in knowledge creation, acquisition and transfer, although they are not necessarily directly aware of the notion of technology transfer. Users are able to give a measure of the success of certain aspects of the social process in advancing the scientific and technological processes in order to create new knowledge and innovation. Participation in meetings, the acquisition of scientific and technological knowledge and skills in different topics, and the development of interests by interacting with colleagues are some of the most effective procedures of the social process in encouraging the advance of the other two processes.

The Finnish and Italian population under study is a good example of the contribution of CERN to the diffusion of innovation. The main elements of the diffusion process of innovation as defined by Rogers [Rog95] (innovation, communication channels, time, and the social system), are all part of the mechanism of knowledge transfer occurring in the samples analysed in this present study. The five stages of the process (awareness, interest, evaluation, trial and adoption) are normally present at various moments during a CERN user's stay, as he or she is continuously exposed to multidisciplinary interaction and innovative techniques and technologies. Although some of the characteristics of the stages of adoption and the rate of adoption have been identified in the respondents through analysis of the questionnaire, the statistics and the type of questions do not probe deeply enough to allow us to present the data according to this theory. More general conclusions of the analysis of this thesis will be presented in Chapter 8.

6.4 Conclusions regarding the research sub-questions

The results obtained for question 18 (positive or negative experience of meetings) show users' active participation in and assessment meetings, especially with respect to project meetings. This provides information on the research sub-question 1: is participation in meetings a procedure of the social process which is effective in advancing the scientific and technological processes?

Responses to question 3 (acquired knowledge per topic) specify skills acquired by users in different fields; they particularly acquire knowledge in experimental physics, computing, technical fields, communication, and science communication. The majority of users declared to have acquired knowledge in financial and managerial aspects. In response to question 4 (list the fields of interest developed or topics studied by interaction with colleagues at CERN or outside CERN) the majority of users declared that they had developed interests not directly related to their specific work activities thanks to interaction with colleagues. Responses to both of those questions can be used to provide information on research sub-question 2: are the acquisition of skills in different topics and the development of interests by interaction with colleagues important indicators of effective scientific and technological processes?

According to the responses to question 16 (participation in R&D projects), the majority of physicists and engineers in both samples are involved in R&D projects. Analysis of the answers to this question revealed evidence of strong social interaction and provides information on research sub-question 3a: if the social interaction between CERN and its users is stronger, will the knowledge acquisition of users be greater?

Trust is one of the requisites for appreciating the quality of relationships between people. Users who are able to evaluate their own personal development show the level of self-confidence needed to develop trust in relationships. This explains why question 14 (what was most important for your personal development?) can provide information on research sub-question 3b: if the quality of the relationship between CERN and its users is higher, will the knowledge acquisition of the users be greater?

In replies to question 14 respondents from both samples accord most importance to working in an international environment and to dealing with a high-level research centre. They are thus able to evaluate their own personal development and appreciate their own level in the hierarchy. The results of the analysis of the responses to question 7 (impact of working in an international environment) confirm the importance of having different contacts, more specifically of having different network ties, for improving knowledge acquisition. The results of both of these questions provide information on research sub-question 3c: if the amount of CERN network ties provided by the CERN is higher, will users' knowledge acquisition from those connections be greater?

Question 17 (was there any technological return or application you are aware of?), can be used in part to provide information on research sub-question 4a: if users' knowledge acquisition increases from the relationship between CERN and its users, will the quantity of inventions developed by the users as a result of that relationship also increase? Among 45 Italians, 28 (23 physicists and five engineers) declared not to have gained any technological returns or applications, and therefore did not recognize the importance of the social process in technology transfer.

In answering question 15 (which technology acquired or skill improved while at CERN has had the greatest impact on your career?), users showed the importance of acquiring technological skills whilst at CERN. The results for this question thus provide information on research sub-question 4b: if users' knowledge acquisition is greater because of the relationship between CERN and its users, will the technology developed by users as a result of that relationship be more distinctive? All these results indicate that social interaction, relationship quality and network ties in a multicultural environment are associated with greater knowledge acquisition. Knowledge acquisition is, in turn, positively associated with competitive advantage in terms of invention development and technological distinctiveness. These results also show that knowledge acquisition plays a mediating role between social capital constructs and competitive advantage outcomes.

Individuals create and expand knowledge through social processes and through the interaction between tacit and explicit knowledge. The capacity to discern one's own contribution to scientific and technological knowledge offers a measure of tacit knowledge which users can share. At the same time the awareness of one's own tacit knowledge allows users to recognize the explicit knowledge that has been converted into their own tacit knowledge. This is why the results from the analysis of the responses to question 1 (your most important contribution from a technical or scientific point of view) can be used to provide information on the main research sub-question: is the way CERN users appreciate their own acquired knowledge a measure of the success of the social process in advancing the scientific and technological processes to create new knowledge and ultimately innovation? For the same reason, evidence related to the main research sub-question may be considered to provide further information on all the previous research sub-questions. The results of question 1 indicate that acquired knowledge appreciated by CERN users is a measure of the success of the social process in advancing the scientific and technological processes to create new knowledge and innovation.

In summary, both the Finnish and the Italian samples show the importance of the connection between knowledge acquisition and social capital by the fact that knowledge acquisition can be acquired through a variety of relationships, which are themselves made possible by working in an international and multicultural environment such as CERN. Already in this initial analysis, Italians highlight the importance of knowledge exploitation in terms of technological innovation and distinctiveness and this could be interpreted as a reinforcement of the link between knowledge acquisition and competitive advantage.

6.5 Significance of the results

Evidence regarding the reliability and validity of the results of the analysis is revealed in the following test. The individual measurements for the study's dependent, independent and control variables and the construction of the measures are also explained.

Knowledge acquisition and the three constructs of social capital (social interaction, relationship quality and network ties) are considered as independent variables. Knowledge acquisition is measured by statements reflecting the scientific and technological knowledge that a user may acquire from CERN. Social interaction is measured by statements reflecting the extent to which the relationship between CERN users is characterized by personal and social ties. Relationship quality is measured by statements reflecting the extent to which users perceive that there is trust between them.

The two outcomes of competitive advantage, invention development and technological distinctiveness, are considered as dependent variables. Respondents were asked to estimate how many products, procedures or technologies they had developed specifically as a result of CERN work experience. The responses varied from zero to four for the Finnish sample and from zero to two for the Italian sample (Fig. 6.5). Technological distinctiveness is measured by statements regarding the extent to which the users' competence in technology is a source of competitive advantage, and is defined as the users' technological skills and knowledge as well as the products and procedures based on these skills and knowledge.

User age and internationalization are considered as control variables. The age of the users has an influence on the user's ability to learn from the relationships with the other users and on the competitive advantage outcomes for the user. Older users may have an experience advantage and younger users may have a higher capacity for the acquisition of new knowledge. The different national background of a user (Finnish or Italian) may also affect his or her level of knowledge acquisition and the outcomes of knowledge acquisition for competitive advantage.

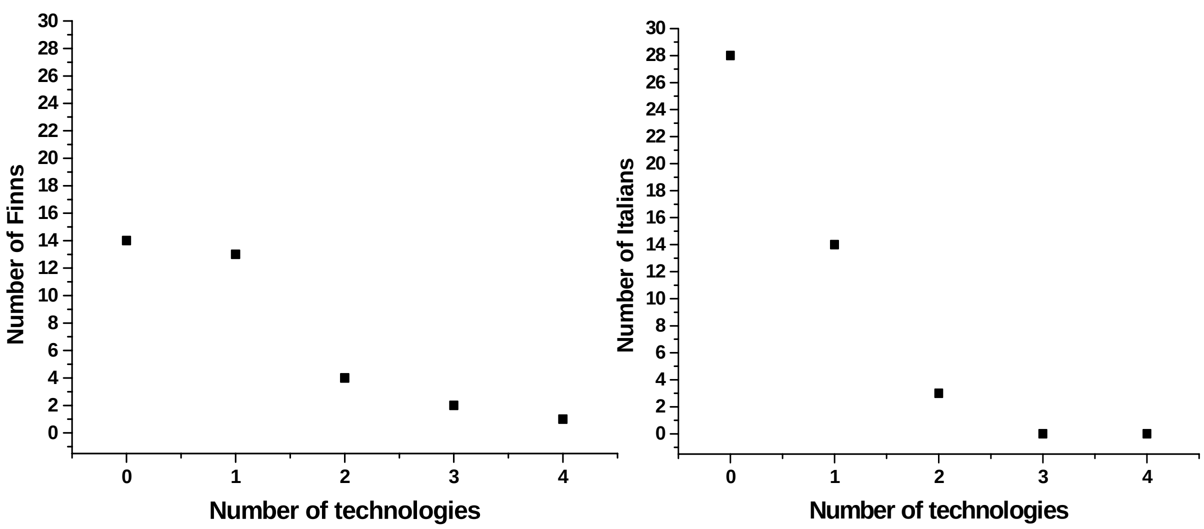


Fig. 6.5: Products, procedures or technologies developed as a result of CERN work. Number of entries: 34 Finns (not including 13 no answers) and 45 Italians (not including 6 no answers).

6.6 Limitations of the study

One difficulty encountered was related to the questionnaire, as it is in part qualitative and in part quantitative. The qualitative part had many open questions so analysis of the answers required selection of keywords to classify the data. From a mathematical viewpoint the quantitative part gave more direct results, but provided fewer personal elements and therefore less explanation. The general keywords chosen for qualitative analysis are knowledge acquisition, learning, skill, know-how, the three constructs of social capital (social interaction, relationship quality, network ties) and the two constructs of competitive advantage (inventions, technological distinctiveness).

In order to limit the questionnaire to a size which could be completed within a reasonable amount of time, the number of cross-check questions had to be limited. Other potential limitations could be due to lack of clarity regarding terminology or difficulty in interpreting some questions. For example, the understanding of the definitions of test, analysis and development in the first part of the questionnaire and the definitions of training and planning in question 7 (impact of working in an international environment). Limitations due to misunderstanding data or possible differences in interpretation can result in some bias in the interpretation but cross-checks were used to reduce this.

7. Knowledge, Social impact, and Communication

This Chapter outlines some concepts of sociological interest mentioning other possible research questions relevant to the current work which could be interesting points of reflection for possible future research work.

7.1 Identity in approaches to science and technology

This Section identifies the sociological concepts that will be used to analyse the research content of this thesis. Two of the central concepts of this analysis are identity and culture. By analysing three important historical processes, namely the civilization process (Elias), the rationalization process (Weber) and the revolutionary process (Marx and Engels), it is possible to define three different forms of identity. The cultural form, which is the community kind and which is the biographical form for others. The biographical form stems from the individual's inclusion in a generational line and is characterized by the name (usually the name of the father). The statutory form is the relational form for others, and, is defined first of all within and through the interaction of an institutional hierarchical system. The introspective form is the relational form for the self that derives from an introspective conscience.

It is impossible to talk about identity without mentioning the concept of other or to raise the notion of individuality without considering the idea of society or group. A person is therefore compelled to create concepts like individual and society [Eli91]. In everyday language, as well as in our scientific conceptualization efforts, we persist in utilizing these two terms as if the realities to which they refer existed independently. Distinction and differentiation are mechanisms closely related to being human and, above all, are necessary in the identification process: there is no possible identification without differentiation. The linguistic differentiation is obvious.

Since ancient times, there have been two main positions regarding the definition of identity. The first is essentialist and describes the existence of an immutable and original essence that is inherent in the entity. It is this that identity portrays. The second is nominal and it considers identity to be a socio-historical construction.

The essentialist position is built on the belief that it is essential realities and substances which are both original and immutable [Dub00]. With regard to cultural identity (linked to a specific culture), the essentialist position does not take reality sufficiently into account.

It is not possible to define and describe the concept of identity without beginning with a number of determinant criteria, considered as objective. Those criteria are the common origin of human beings (hereditary transmission, genealogy), language, culture, religion, collective psychology (basic personality) and the bond with a territory. In this view, identity is conceived as a fact which identifies once and for all the entire individual and outlines him or her indelibly. Considered in these terms, identity appears to be an essence, which is not open to development and which the individual or group cannot obtain. Identity lies therefore in a sense of 'belonging' inherent.

Cultural heritage is tightly linked to the socialization of an individual in his or her cultural group. The individual is driven to internalize the cultural models imposed on him or her to the point that she or he is able to identify himself or herself only with his or her group of origin. Cultural identity appears, then, correlated with a specific culture. It is therefore necessary to try to establish the list of cultural attributes that are supposed to a support cultural identity and to try to determine the immutable cultural elements that define the essence of a group, in other words its essential identity. Described in these terms, cultural identity appears as an inherent and essential property specific to a particular group, a property conveyed through and to the group without any reference to other groups [Cuc96].

Identity can also be regarded as the result of a double operation of differentiation and generalization. From this standpoint there is no identity without the concept of other. Identity varies according to historical background and depends on the context of definition [Dub00]. There are two heterogeneous processes rather than a single mechanism: the first being identity attribution —which cannot be analysed outside the systems of action in which the individual is involved; and the second being active internalization — the incorporation of identity by the individuals themselves. These two heterogeneous processes contributing to identity formation — biographic (identity for oneself) and communicational and relational (identity for others) — nevertheless adopt the common mechanism of referring to classification schemes involving the existence of different types of identities [Dub96].

The socialization process points to the interaction and transaction processes between a human organism and a specific social environment. This environment lasts throughout life [Hut97]. Several social groups normally interrelate. A counter-culture the appearance and the emergence, within a group, of values that are in opposition with other values of the group: the concept of counter-culture then questions the values established by the common culture [Bon88]. The counter-culture strength creates the appreciation of specific behaviours and becomes a source of pride to the individual, identifying him or her with the counter-culture. In this sense, rebellion against the established order may be a structural peculiarity of identity formation [Kau92]. The feeling of belonging to a counter-culture, which questions the dominant values and norms of the culture, determines some of the cultural characteristics that allow the active identification of the individual with his or her group sub-culture.

Culture is mainly a matter of unconscious processes. With regard to identity, though, we can see that the concept refers to a standard of belonging (or membership) that is necessarily conscious. The social identity of an individual characterizes itself through the feeling of belonging to a part of the social system: belonging to a sexual class, to a social class, to an age class, to a nation, etc. Identity enables an individual to locate him or herself in the social system and, at the same time, to be socially identifiable. Social identity, though, does not involve individuals only. Each group is endowed with an identity that corresponds to its social definition – this definition facilitates the location of the group in the social system.

Social identity is simultaneously inclusion and exclusion: it identifies the group and distinguishes it from others. In this view, cultural identity is a way of categorizing the distinction 'us and them' based on cultural difference. There is no identity in itself or by itself; identity is always a relation to the other. In other words, identity and otherness are linked and have a dialectical relationship. Identification goes together with differentiation. Identity is always the result of an identification process within a relational situation. The identity constructs, deconstructs and reconstructs itself depending on the situation. It ceaselessly moves and every social change drives it to a new shape. All identification is in itself a differentiation [Cuc96; Rig01].

7.2 Other possible research questions

Is culture part of identity or does identity stem from culture? One of the author's hypotheses is that scientific identity is a culture in itself. Culture is a process. This process creates hierarchy and forms groups, where individuals and groups interact. Interaction is the key point of the cultural process. Starting with a social analysis, the internal interaction (inside the group) has to be strong enough to create an identity resistant to external interaction, which could destroy the identity. It is the individual, however, who constructs her or himself by trying to comprehend his or her identity and elaborating personal connection with others. This construction is always contingent (as it depends on social and historical context and process) and each single person and group attributes some specific meaning to it. In attributing some specific meaning to construction of self a more constructivist approach is adopted. The initial general research paradigm of this thesis considers scientists as a specific linguistic and cultural minority. The level the scientists have reached in the scientific hierarchy binds them together as an identifiable community. In particular, this paradigm portrays the scientists as the carriers of an intrinsic specificity that determines both the use of a particular language and a strong sense of identity. The HEP community can be considered as a specific social group within the scientific community, group where ideas and knowledge are exchanged on the basis of scientific knowledge and innovation, and cultural barriers are overcome.

Some additional questions deriving from what this discussion of scientific identity are:

- What are the elements that allow us to comprehend the scientists as a linguistic and cultural community?
- Around which specificities are scientific identity, its cultural particularities and its belonging to a scientific community constructed?
- What importance do these dynamics have in the non-scientific world?

These open questions are not the main work of this thesis but could be interesting points of reflection for encouraging possible future research work and the author suggests some hypothetical answers:

- Scientific language is the centre of the identity's construction and of the feeling of belonging to a community, causing a specific cultural base.

- Scientific language is also regarded by the majority of non-scientists as the heart of the scientific world: it represents the opposition of interests in the relationships between scientists and non-scientists. Mastering scientific language and having a good knowledge of scientific culture are two of the criteria that determine whether for a non-scientist is able to communicate with the scientific community.

7.3 Scientific values and technological needs: a new dimension of knowledge

The purpose of scientific research in general, and physics in particular, is to find new laws to describe nature. It is pursued with the purpose of understanding phenomena and explaining the world in which we live. To understand phenomena, comprehension of the scientific process is important, but to enjoy the world, which means satisfying our needs, the technological process is essential. More and more often society asks physicists to explain what advantages society has gained and can expect in the future from fundamental research. To answer society effectively, it is important to remember that society wishes to use technological products because it wants to enjoy life. This means coupling the industrial and commercial life via technological process.

In synthesis, in many cases, science has changed for the better and technology leads to economic growth. Is it really possible to get any commercial use, and then benefit to society, from scientific knowledge? To solve the ethical contradiction between the purpose of science and life needs it is necessary to find an acceptable compromise, as CERN and other international scientific centres have worked out in creating a culture of technology transfer.

There are mainly three types of direct benefit to society from physics research: the first is due to the possibility that entirely new fields of technology may be created and the second to the pioneering technology created for solving technical problems. Thanks to the introduction of new scientific instruments, it is possible to improve knowledge acquisition. This yields the third type of benefit, which, as this research study shows, is the most important: the transfer of acquired knowledge. The most efficient way of transferring knowledge is transferring people. Personal knowledge and skills are a valuable form of technology transfer. The expertise acquired at CERN running major physics experiments is diverse: computing, electronics, project management, communication, etc. In addition, there are the interpersonal skills gained from being a member of a large multicultural team working on a complex problem.

7.4 Social impact of working in a research organization

Question 21 of the questionnaire is *"did your stay at CERN have an influence on your cultural interests outside your country of origin?"* This question probes a sociological point and aims at determining whether the stay at CERN modified any cultural habits and facilitated cross cultural know-how acquisition. This question and all its related fields, holiday, language, food habits, and sport and hobbies, can be used in this analysis and is part of the social process. Table 7.1 shows the number of users, Finnish and Italian, who answered this question.

Table 7.1: Question 21: Influence on cultural interest outside your country of origin.

Categories	**Finns** (n = 43, no answers = 4)	**Italians** (n = 49, no answers = 2)
Physicists	23	35
Engineers	17	14
Administrators	3	

Results from the analysis of the replies to this question show that the staying at CERN has had an influence on cultural habits with particular regard to holidays, food habits and language among the Finns; whereas Italians benefited most in the matter of language (Fig. 7.1).

Respondents were also asked to complete an open section of the questionnaire, allowing comments. The majority of users (26 Finns and 37 Italians) did not complete this part. Some users mentioned the difficulty of completing the questionnaire because of the lack of clarity regarding terminology or difficulty in interpreting a few questions, or because they experienced CERN long time ago or only for a limited period. Some respondents found a few questions not applicable because they were still working at CERN. Other statements differed again, and reported below:

1. "*In general, my opinion of CERN has dropped down during the years I have been at the laboratory. I have seen many people around me being not so happy for the*

work and leaving this place, especially for the private business areas. Or I have seen people just staying here because of the money. With this I mainly want to say that the glamour of CERN is not the same anymore it used to be. But finally, I think CERN has been a nice and interesting place straight after university studies: good, easy and safe start for the working life."

2. "*To work at CERN has been a positive experience from a scientific and cultural point of view.*"
3. "*CERN is making cross-fertilization to industry and I am very proud to be part of it.*"
4. "*The multicultural environment could be positive but also negative; at CERN, for example, when the Director-General changes, the nationality changes and then the general mentality of the Laboratory.*"

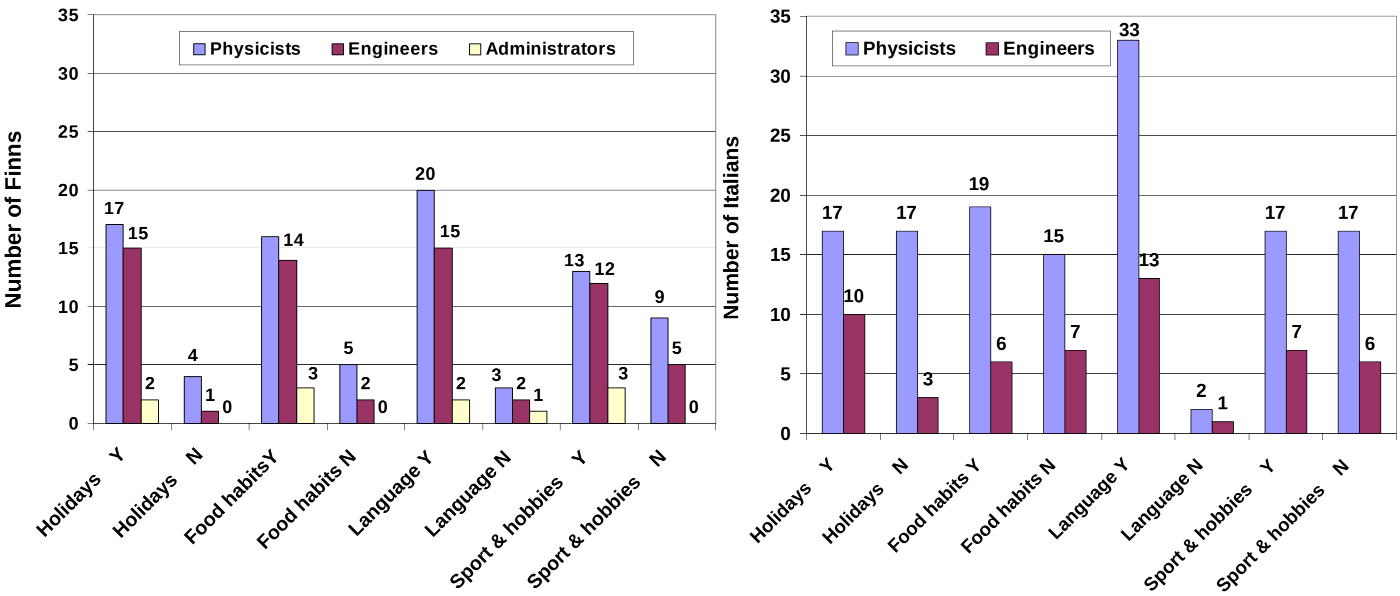


Fig. 7.1: Question 21: did your stay at CERN have an influence on your cultural interest outside your country of origin? Number of entries: 43 Finns (not including 4 no answers) and 49 Italians (not including 2 no answers).

7.5 Science and technology communication: needs for the physics community

There is no overall form of scientific communication, but rather different levels. Scientists are often highly specialized in a very specific research branch, and when confronting with each other or while discussing amongst themselves are mediating at a very high level. The world of science and technology information is a delicate process of conciliation, which allows messages to flow at its various hierarchical levels. Scientists, industry and the audience represent a complex triangle involved in a sensitive game of scientific knowledge transfer [Bre98].

The lack of interaction among scientists, industry and the audience is the fundamental problem for science communication and technology transfer. It stems from a disparity of intent; between what is conceived to be the final goal of science on the one hand and of technology on the other. Instead of forcing the parties of the triangle to strengthen their collaboration, this disparity in fact weakens them. Nowadays, in an effort to avoid incomprehension, both the science and the technology environments are becoming more aware of this reality and the current situation is therefore evolving. As a proof of this evolution, witness the attempt to acknowledge the technology transfer officer's true professional status. Scientists are also both emphasizing and recognizing their unease sense of when conveying scientific information, and are encouraging wider collaboration between all three parties. The right balance has been reached on only a few occasions and then with small organizational structures. The coordination of these specific situations could be a step forward in the development of an effective scientific communication and technology transfer strategy.

Another point emerging from this study regards the choice of language. This is another delicate issue, which still needs to be properly defined and addressed. How to explain science to the uninitiated while maintaining scientific rigor? Should there be a return to the narrative dimension in science or should the result and the general laws found to be the basis of this or that research be described more formally? The answers to these questions still seem too vague to provide a global solution. Instead, the non-scientist must be brought closer to science and technology. How could this be achieved? One suggestion is to create a generic text, which starts from a simplified and accessible level, which conveys right information, and which moves through ever more complex levels.

Text, scientific or not, is one of the forms that the product of a linguistic act can take. It can only be said that a text is adequately organized when we consider it from three defined parameters: the context, the recipient and the intention of the communication. In other words, once those three parameters have been reached it can be said that a text will be coherent if it will produce cognitive effects with the minimum expenditure of mental elaboration. This involves finding criteria that will allow generalizations of any kind of scientific text elaboration and will prevent illegitimate generalizations, as well as criteria to carefully identify the conceptual structures of the original text. A distinction must be made between the information we want to convey and the implicit reasoning that lies behind it — this is achieved through exemplification, analogical description and, where suitable, metaphorical explanation, which assist the deductive capacity of the reader.

Science and technology, as with every knowledge field, is a too wide domain for those who claim to know everything. Individuals must find a defined and acknowledged space within the communication structures. Science and technology communication should be considered in a more general context, a context involving everyday life interests of everyone (see Appendix F).

8. Conclusions

This research study started by aiming to provide answers to two main questions. The first question addressed the educational impact of an inter governmentally funded scientific centre, CERN, in order to evaluate what competitive acquired knowledge and core skills people develop and to determine the market value of their skills for CERN Member States' industries. The second question aimed to investigate how exposure of people to an international environment enhanced their cultural or social dimensions, and how society benefits from this exposure. In order to analyse these questions a knowledge creation, acquisition, and transfer framework model was created and verified by the research sub-questions. Other research sub-questions can be derived from the model, but the questions were in this case limited by the need to keep the size of the questionnaire reasonable.

The interest of the present research is twofold. First, it represents the first quantitative and comparative assessment of knowledge acquisition of physicists and engineers who have worked at CERN and is also the first analysis investigating if different nationality, and therefore different academic curricula and cultural differences, can affect knowledge perception, learning and acquisition. Second, it is the first time that the environmental and multicultural aspects and interactions generated by a 'big science' organization with scientific aims and high technological distinctiveness have been investigated among individuals sharing a strong common scientific identity.

The results obtained have been referred to the above-mentioned model, which takes into account the scientific, technological and social processes of knowledge acquisition and the four modes of knowledge conversion from tacit to explicit. The impact of this research and model (before publication) has already been to generate interest both within the Institute of Physics Education of the University of Helsinki and CERN to test further the model by investigating the factors that favour or slow down technological innovation and the transfer of knowledge with respect to several specific high-technology developments. The analysis of these factors will have an impact on the understanding of the correlation and relative weight and importance of the various phases of the innovation process of the model and hopefully lead to an optimization of knowledge management procedures and communication tools, including the choice of the appropriate language, which will:

- make the acquisition of knowledge more efficient;
- enhance dissemination; and
- improve technological learning.

It is commonly accepted that we live today in a “Knowledge Society” [Dru93], and in contrast to the former industrial society, where knowledge used to be just a resource, today *knowledge is the resource*, the key factor in innovation. Globalization and the technological society, boosted by economic and technological developments (i.e. information and communication related technologies) have determined the importance attributed to the knowledge creation process at the organizational level by managers of large multinational companies as the means to increase company competitiveness and in particular the creation of innovative products or services.

The present and subsequent research and the model presented here will be instrumental in bridging the gap existing today between the industrial and scientific world in the field of knowledge management. This research may have a political impact as it confirms, with quantified data, and conceptualizes the role CERN has played over the past 50 years as a leading organization in creating knowledge, not only in the field of HEP but also in related technological fields. It also makes explicit the importance for individual and organizational knowledge creation of the multicultural scientific and technological environment, where many students, scientists and engineers are embedded in a scientific atmosphere and are given the opportunity to confront and to interact with a vast array of technical and scientific specialists. CERN as an organization has its own epistemology, with its own tacit and explicit knowledge and creating entities (individuals, groups, organization), which in turn have their own ontological dimension. The mode for the creation of knowledge remains the same in a national context or in a multinational company, but the conditions enabling the process and amplifying it are largely different due to the importance of the social process — as the results obtained in the present research sustain (See Sections 3.3.3, 6.1.1, 6.1.3, and 6.1.5).

The study of knowledge creation has been, since ancient times, a subject for philosophers or educators, and only more recently for sociologists and economists. Due to the specific needs created by the development of artificial intelligence a new sector of study on knowledge acquisition, focused on concepts and meaning, is presently developing. The need to understand how innovation is created and how companies should manage knowledge has fuelled more research into technology departments. The majority of these studies investigate knowledge creation in firms, in particular how human capital is incorporated into structural capital by means of routines; how the quality and cognition of actors mediate innovation; how to enable knowledge creation [Non01; Kro00]; the role of tacit knowledge in the management of innovation [Sei03]; and the impact of cyber society on knowledge creation [Hip02]. CERN is an ideal place to test and valuate theories and models on knowledge acquisition, and some to carry out quantification of knowledge management in order to enhance innovation productivity.

The model developed in this study is the only one that could be applied to CERN's specific environment, where scientific knowledge is deeply bound technological knowledge and is largely mediated by the social process. Large multinational companies today largely appreciate technological knowledge and the social process. At CERN, however, technology simply represents the way to make available to European physicists installations whose cost would be prohibitive for a single nation alone, installations or equipments that are, at CERN, using cutting-edge technologies at reasonable cost and using limited manpower. Furthermore, as the model applied in companies does not take into account the scientific knowledge acquisition that is the primary role of CERN, this model provides researchers in knowledge management with the opportunity to analyse and stimulate further scientific knowledge creation.

A research project is currently in progress [Bre04] on the detailed analysis of knowledge creation in the technological process as described by the model proposed in this thesis. Its aim is to investigate the interaction patterns leading to innovative product development, as well as the appropriate language and the level of communication needed for education purposes.

Results from this thesis research, carried out on Finnish and Italian users of CERN indicate that individuals create and expand knowledge through a social process, and that there is an interaction between tacit and explicit knowledge. This is especially evident where individuals have to discern their own contribution to scientific and technological knowledge, which offers a measure of the tacit knowledge that users are able to share. At the same time, awareness of one's own tacit knowledge gives individuals the opportunity to recognize the explicit knowledge resulting from new knowledge, to acquire it, and to convert it into new tacit knowledge. The results of this research show that the acquired knowledge discerned by CERN users is a measure of the success of the social process in advancing the scientific and technological process, ultimately leading to new knowledge and innovation.

Furthermore, results indicate that social interaction, relationship quality, and network ties in a multicultural environment are associated with knowledge acquisition. Knowledge acquisition is positively associated with competitive advantage in terms of invention development and technological distinctiveness and plays a mediating role between social capital constructs and competitive advantage outcomes. These aspects have only been tackled incidentally by this study and need to be more specifically researched in terms of correlation and outcomes.

The analysis carried out allowed a general description of the various paths of students' and engineers' knowledge acquisition and transfer and their researches deriving from the CERN experience. These are reported in Figs. 8.1a and 8.1b and represent an additional outcome to the study also which could prove the basis for further investigation.

Finnish and Italian physicists and engineers have acquired skills in different domains: experimental physics, computing, technical fields, communication and science communication. In addition, several Italian physicists and Finnish engineers have acquired knowledge in finance, management and social skills. Software, computing, and electronics represent the fields in which the majority of Finns and Italians have acquired the most technological distinctiveness.

All respondents confirmed the importance of interacting with their colleagues inside and outside the Organization and of being confronted with different disciplines and technologies, especially in order to develop interests not directly related to their specific work activities and to improve their knowledge acquisition. CERN users participate actively in meetings; Finns and Italians underlined that their most important experience at CERN was the opportunity to work in an international environment and at a high-level research centre. They recognized the importance of having continuous scientific stimulation much more at CERN than in other work place. They appreciated the advantages of working in an international environment, including discussion with colleagues, living abroad and broadening cultural aspects. Most declared that it was very useful to attend seminars and lectures to keep up-to-date on recent scientific results and to expand their knowledge in areas not directly related to their competence. This shows that they fully appreciate the role of the social process in scientific and technological knowledge acquisition in acknowledging the role of the interaction among people in the working environment.

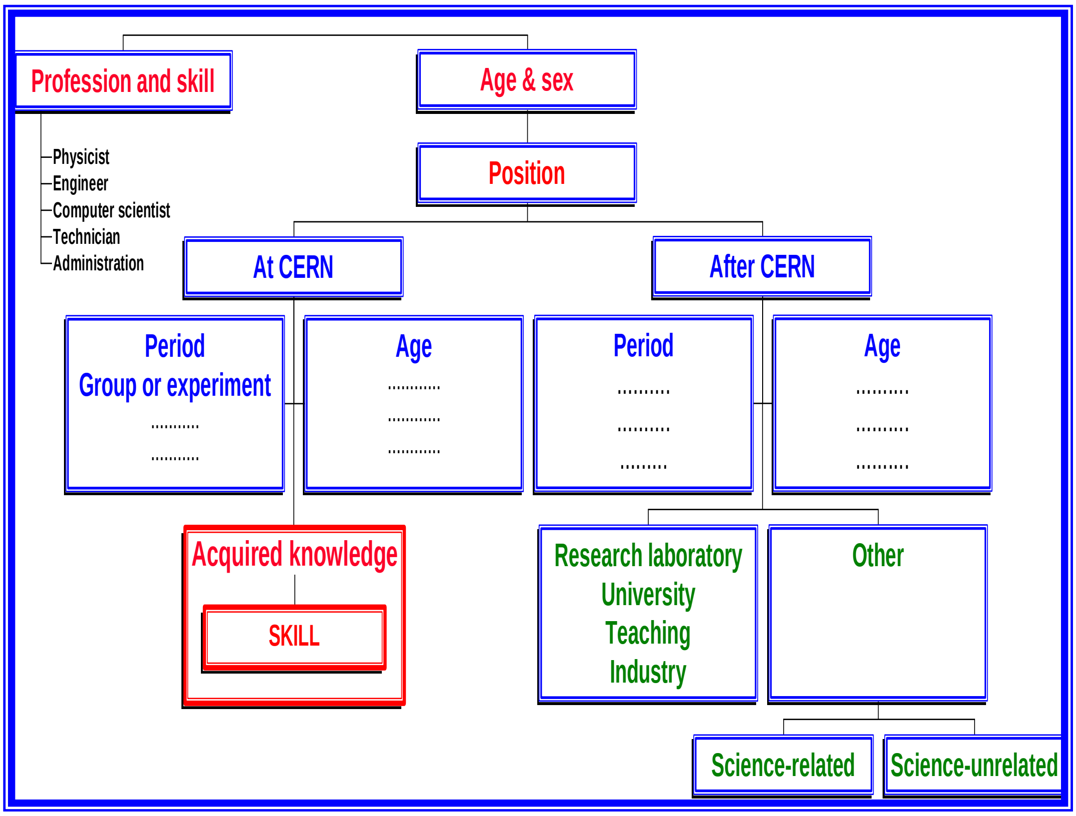


Fig. 8.1a: Users and CERN knowledge acquisition schema.

Users identified reasons for their dissatisfaction as the excess of bureaucracy in CERN management, business and administration, and the tendency in recent years to organize research work in too systematic a manner. As an improvement some users suggested more consideration should be given to the industrial approach to improve management and to encourage meetings between people from different experiments, to share experiences and to encourage communication.

In summary, this research study provides evidence for the observation that the expertise acquired at CERN running today's major physical experiments and technical sectors is diverse. Results confirm the important educational impact of the Laboratory for visiting students, engineers and researchers who, by being at CERN, have the opportunity to acquire competitive knowledge and high-level core skills. In conclusion, the transfer of acquired knowledge through people represents important direct benefit to society this Organization. These acquired skills enable people to develop market value in Member States' industries. Further interesting aspects tackled but not specifically studied in this research are the identity and the culture of the HEP community, its relation to the non-scientific majority, and the challenge represented by power struggles in today's technology and information society. The author has already made some suggestions for encouraging further research in these areas.

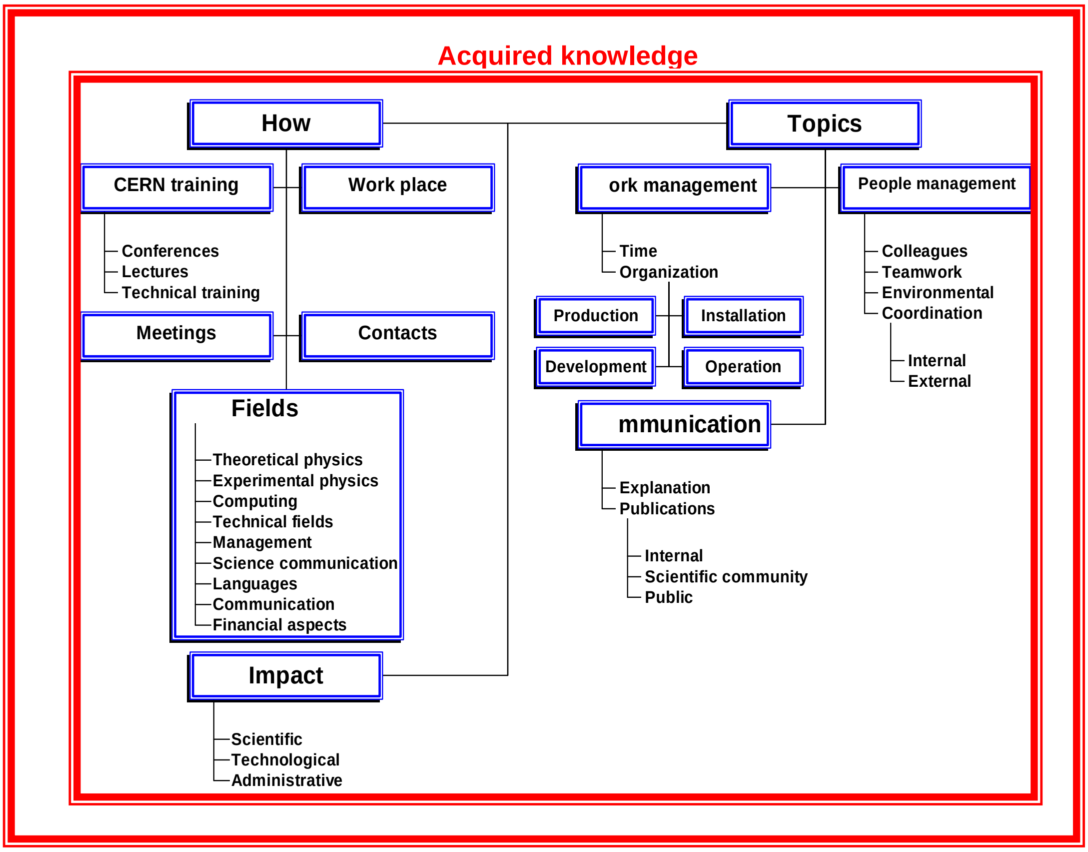


Fig. 8.1b: Different paths of CERN acquired knowledge and know-how.

The model developed by this research is relatively complex. It has, however, the advantage of being able to integrate and explain the knowledge creation processes typical of a scientific international research organization with an educational and technological vocation.

The model derives from two separate models: Kaarle Kurki-Suonio's model regarding education in academic environments and Ikujiro Nonaka's model regarding knowledge management in industrial environments. These two models focus on the knowledge acquisition process and on the knowledge transfer process respectively. The peculiarities of CERN, where the two worlds of academia and industry are both present, require a new model, where these two environments can be represented and unified in terms of knowledge creation, acquisition and transfer. The new model presented in this thesis is able to absorb and allow the analysis of knowledge creation, acquisition and transfer, to underline the importance of the scientific process, and to correlate how, what and when the three processes (scientific, technological and social) interact at individual and organizational level.

Furthermore, the new model identifies the parameters governing the process of knowledge creation, acquisition and transfer. The author has particularly emphasized the assessment of the social process and the correlation between the variety and quality of interaction and knowledge creation within CERN.

A possible critique of the new model concerns the need to find a way to better quantify knowledge creation, acquisition and transfer. It would also be valid to ask whether the model could be simplified and still remain accurate? For the moment this seems to be rather difficult to achieve.

Organizations and companies measure many things in the course of their activities. But are they measuring the right things? Do the measures reflect their strategies and objectives? Do they have indicators that identify where action needs to be taken? Do they have accountability linked to measures? Measuring knowledge management is not simple. Determining knowledge management's pervasiveness and impact is analogous to measuring the contribution of marketing, employee development, or any other management or organizational competence. It is nonetheless necessary if knowledge management is to have significant impact in an organization's leading role and innovative capacity. For companies the need for measurement of knowledge management follows a bell curve pattern through a business cycle. In the earliest stages of knowledge management implementation, formal measurement rarely takes place, nor is it required. As knowledge management becomes more structured and widespread and companies move into different stages the need for measurement steadily increases. As knowledge management becomes institutionalized — a way of doing business — the importance of knowledge management-specific measures diminishes, and is replaced by the need to measure the effectiveness of knowledge-intensive business practices. The same is likely to occur in organizations, with some adaptation: businesses and products will be replaced by top-level research outcomes and cutting-edge technological equipment. To answer to the above-mentioned questions could be important for managing knowledge through the life cycle of a large project, such as the LHC at CERN, although this research cannot provide any data.

Fifty years of CERN have contributed to knowledge creation, acquisition and transfer and this contribution can be measured using, for example, the number of publications or number of visiting students. The model constructed for this research study is a structure type and provides only a description of the measured parameters at the base of the structure. The research carried out has quantified only the average scientific and technical contribution of CERN users (Tables 6.3a and 6.3b), a share of knowledge creation by interaction (Table 6.5) and the impact of the international environment and training on CERN users (Tables 6.6 and 6.7).

By introducing knowledge management concepts to science, this model helps to reduce the gap between the scientific and the technological worlds, as these concepts have so far been limited to companies and information technology.

Finally, can the CERN knowledge creation, acquisition and transfer model be applied to nationalities other than Finns and Italians? For practical reasons, this research was limited to those two nationalities, but the future belongs to organizations that can take the best of their employees and users and build on a global model of knowledge creation and innovation based on scientific and technological knowledge acquisition. In a global research organization such as CERN nationality has no relevance and does not determine the key characteristics of success, as seems to be confirmed by this research. Success is related to knowledge creating capabilities, and CERN should take this into account. To become effective in creating and transferring knowledge, organizations such as CERN need to build and manage multiple processes, involving dynamic, interactive, and simultaneous exchange inside and outside the organization. This includes more partnerships and interaction with the industrial world to fuel a more pro-active method for day-to-day innovation. A recent study evaluated technological learning in CERN's suppliers [Aut03] and advocated partnership with industry to boost learning, increase competence and produce innovation. The speed by which exchange and synthesis take place between scientists themselves and between scientists and industrial actors will be the key factor for innovation in future. The CERN context, where new knowledge is constantly been created, disseminated widely throughout the Organization, and rapidly embodied in new technologies, products, and systems, can achieve innovation. The knowledge creation, acquisition and transfer model developed by this research study could be considered as universal in terms of applicability.

Assessing the factors that contribute to knowledge acquisition is a complex task and an inexact science. This thesis has shown some interesting results but it is clear that much was learned and much could be improved, in particular, with regard to the following developments:

- A more targeted analysis of the interrelation between the basic elements of the model (scientific, technological and social process).
- An analysis of the differences of the interrelation according to fields of knowledge.
- An improvement of the relationship between the three basic processes of the model and the questionnaire.

It is the hope of the author that this work will stimulate further activity in this area and will prompt an improved rigorous approach that will lead to concrete advice for organizations in improving knowledge acquisition, retention, build-up and transfer by individuals.

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Appendix A: Brief history of Internet and WWW

The revolution in human telecommunications started on 1836 when Cooke and Wheatstone patented the telegraph but the cable can be considered the first base of Internet. The Atlantic cable of 1858 was established to carry instantaneous communications across the ocean for the first time. It was a technical failure: it only remained in service a few days. In 1866 cables laid were completely successful and remained in use for almost 100 years. Ten years later came the telephone and today telephone exchanges provide the backbone of connection. The Internet itself by definition was born at the crossroads between the computer and telecommunication Industry. On 4 October, 1957, the USSR launched Sputnik, the first artificial satellite to successfully orbit the Earth, causing the development of space technology to become a national priority in the U.S.A. and marking the beginning of global communications, focusing on computer networking and communication technology. After the Sputnik, US President D.D. Eisenhower saw the need for the Advanced Research Projects Agency. The Atlantic cable of 1858 and Sputnik of 1957 were two basic milestones in Internet prehistory. In 1962 Dr J.C.R. Licklider was chosen to head ARPA's research in improving the military's use of computer technology. To quickly expand technology, Licklider saw the need to move ARPA's contracts from the private sector to universities and laid the foundation for what become the ARPANET. Between 1962 and 1968, P-S network technology was developed to transform secure data into tiny packets that may take different routes to a destination. The birth of the Internet, namely the technical infrastructure consisting of a global network system, occurred in 1969 with the first node at UCLA closely followed by nodes at Stanford Research Institute, UCSB and the University of Utah (4 nodes in total). In late 1971, L. Roberts at Defence Advanced Research Projects Agency decided that people needed serious motivation to push technology forward and people started communicate over a 15-node network. In 1972 there was an International Conference on Computer Communication with the first public demonstration of ARPANET (Fig. A.1) between 40 machines. One year later global networking becomes reality thanks to the first international connections to the ARPANET. In 1976 Queen Elizabeth of the United Kingdom sent an e-mail and one year later e-mail took off.

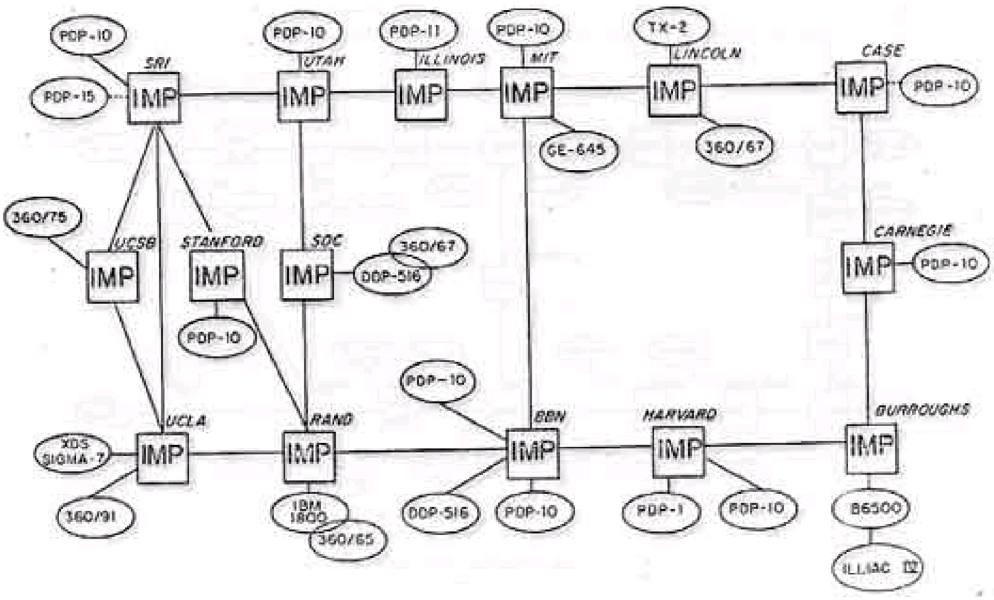


Fig. A.1: Logical map of the ARPANET, April 1971.

It would have been impossible to benefit from the advantages of the Internet without the research completed at CERN in the last decade of the twentieth century when the WWW came into being. Indeed, the Web was originally conceived and developed to provide a common method to distribute information across the world from any desktop computer for the large physics collaborations which demand instantaneous the information sharing of amongst physicists working in different universities and institutes all over the world. At the end of the 1980s the Web was CERN's response to a new wave of scientific collaboration. In 1991, T.B. Lee released WWW at CERN. Understanding immediately its importance and profiting from its research scopes, Industry positively influenced the acceptance and spread of Internet techniques in Europe and elsewhere. Just two years later a WWW revolution begun and on 1994 there were 3 million hosts, 10,000 WWW sites and 10,000 news groups. In 1996 Microsoft entered the market and the WWW browser war begun, fought between Netscape and Microsoft. There where 12.8 million hosts and 0.5 million WWW sites. As the collaborations reach their conclusion CERN is preparing a new scientific instrument, the LHC, for a new generation of experiments. To date, the computing requirements of the LHC's experimental collaborations are unprecedented, far exceeding those of other fields of science or branches of industry and commerce. 1999 was the time to start thinking about the new Internet implementation: the GRID.

Summary of the main dates of history of WWW and Internet:

- **1836** Cooke and Wheatstone patent the Telegraph.
- **1858** Transatlantic cables were developed until 1866.
- **1876** Telephone saw the light.
- **1957** USSR launches first artificial earth satellite: Sputnik.
- **1958** DoD created ARPA.
- **1961** DDR&E assigns a Command and Control Project to ARPA.
- **1962** IPTO formed to coordinate ARPA's command and control research.
- **1962** P-S networks developed until 1968.
- **1969** Birth of Internet.
- **1971** People communicate over a network by 15 nodes on ARPANET.
- **1972** ARPA renamed DARPA.
- **1972** First public demonstration of ARPANET.
- **1973** First international connections to ARPANET.
- **1977** E-mail takes off: Internet becomes a reality.
- **1986** The technical scope of IPTO expands and it becomes the ISTO.
- **1991** ISTO splits into the CSTO and the SISO.
- **1991** WWW released by CERN.
- **1993** The WWW revolution truly begins: 2 million hosts. 600 WWW sites.
- **1994** Commercialization birth: 3 million hosts, 10,000 WWW sites, and 10,000 news groups
- **1996** Microsoft entry: the WWW browser war begins, fought between Netscape and Microsoft.
- **1999** Birth of the new Internet implementation: the GRID.

Appendix B: How to access TT database

The figures illustrate step by step how to access to the TT items as technologies, special projects, patents, etc., starting from the CERN Web page 'Relation with industry', accessible on the CERN Homepage (Fig. B.1): how to select a technology (Fig. B.2), how to call a Simple Search Form (Fig. B.3), and how to use a Simple Search Form (Fig. B.4). For an advanced search it is necessary to enter into the Search Form page (Fig. B.5), and get the available list of technologies according to the selected criteria (Figs. B.6, B.7, B.8). Figs. B.9, B.10 and B.11 show how to access to the details of a specific technology and to find the related information as documents, references and contacts. It is also possible to get details of each TT item related to technologies or special projects (Figs. B.12, B.13, B.14) [Rog02]. The Web form available for the general public is accessible from the CERN general public site: http://public.web.cern.ch/Public/ (pulldown the 'Technology' and the following 'If you want to know more' and select 'Technology and Industry' and finally 'CERN Industry and Technology Liaison Office') (Fig. B.15).

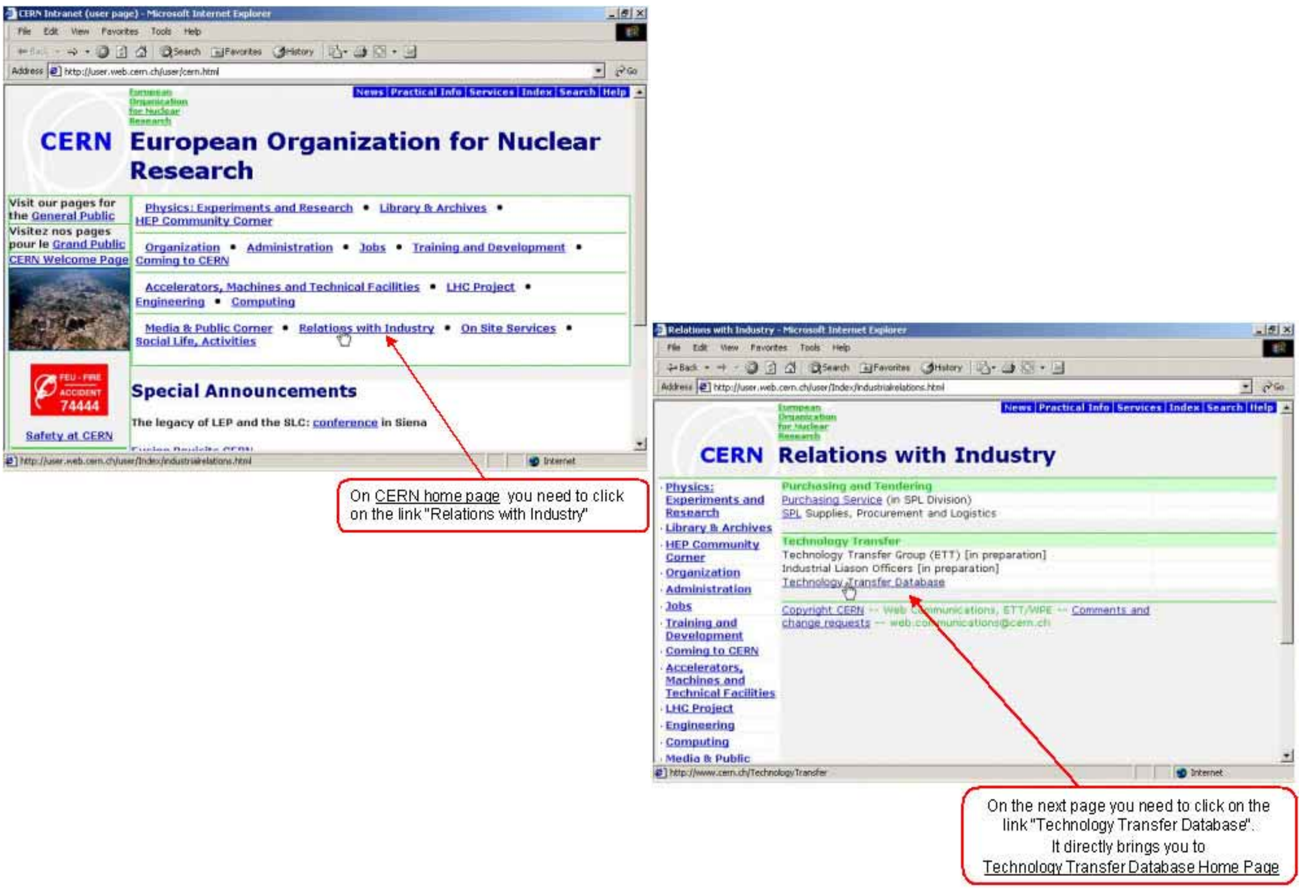


Fig. B.1: How to access the TT database from the CERN home page.

Fig.B.2: Step 1: select Technologies.

Fig. B.3: Step 2: call Simple Search Form.

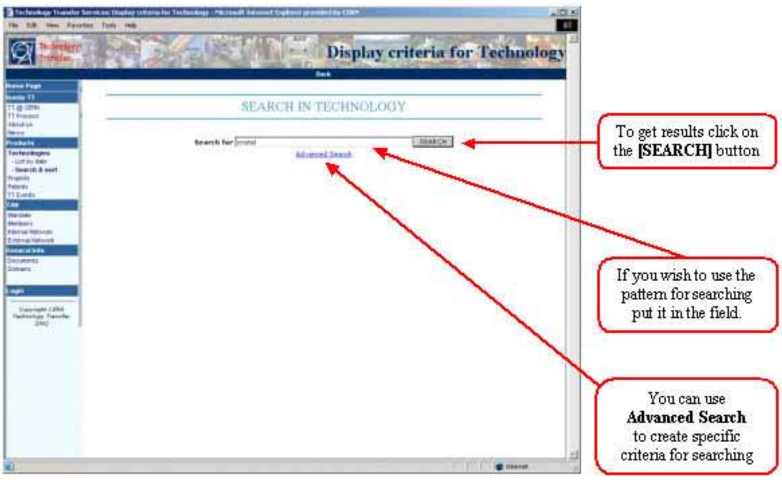


Fig. B.4: Step 3: using Simple Search Form.

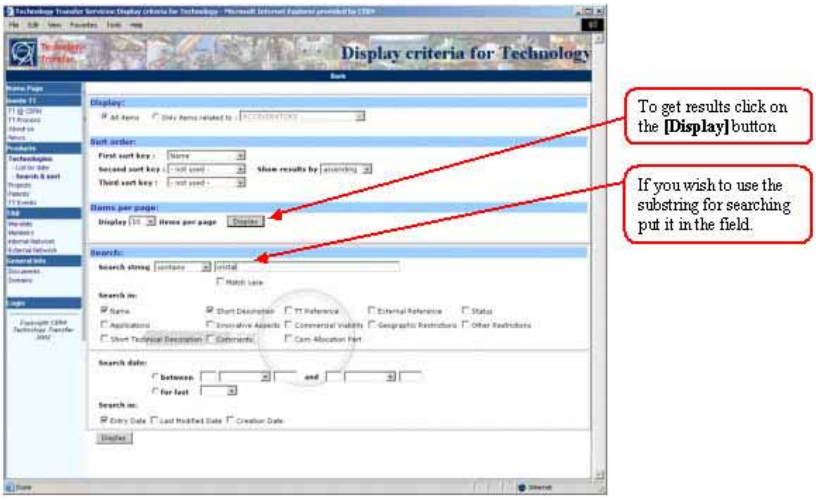
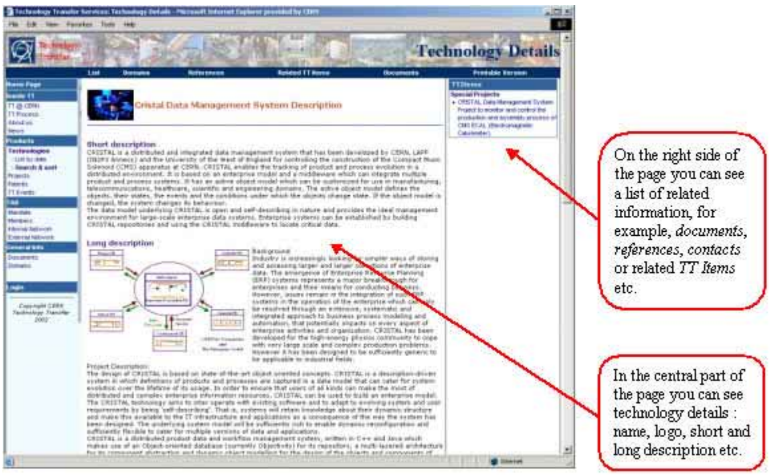


Fig. B.5: Search Form page of the TT database.

Fig. B.6: Select a technology

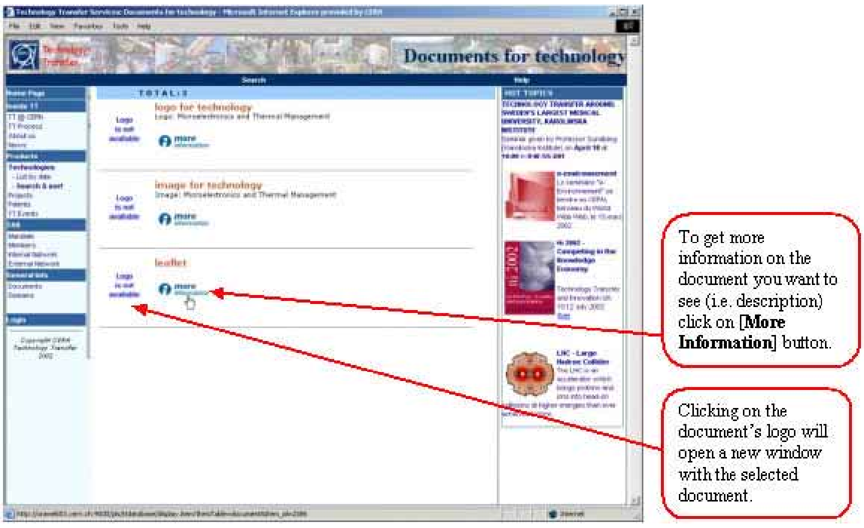
Fig. B.7: Select details of technology.

Fig. B.8: List of items according to the selected criteria.



Figs. B.9: How to access to Technology details.

Figs. B.10: How to access Technology related documents.



Figs. B.11: How to find related information on technology details.

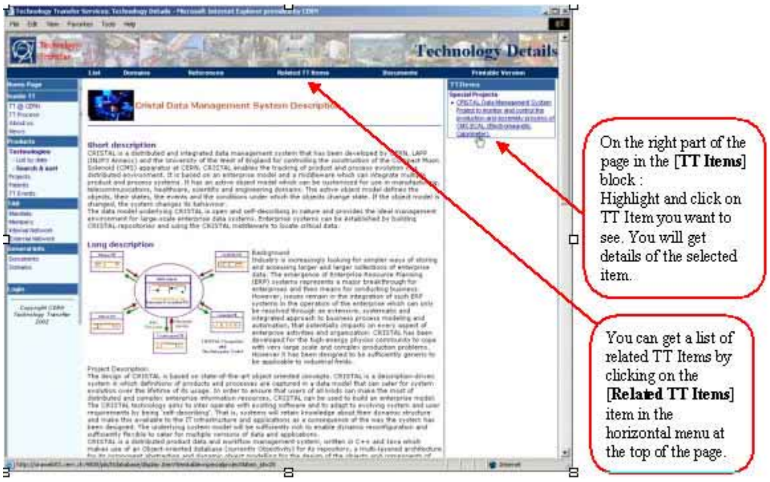


Fig. B.12: How to see related TT items.

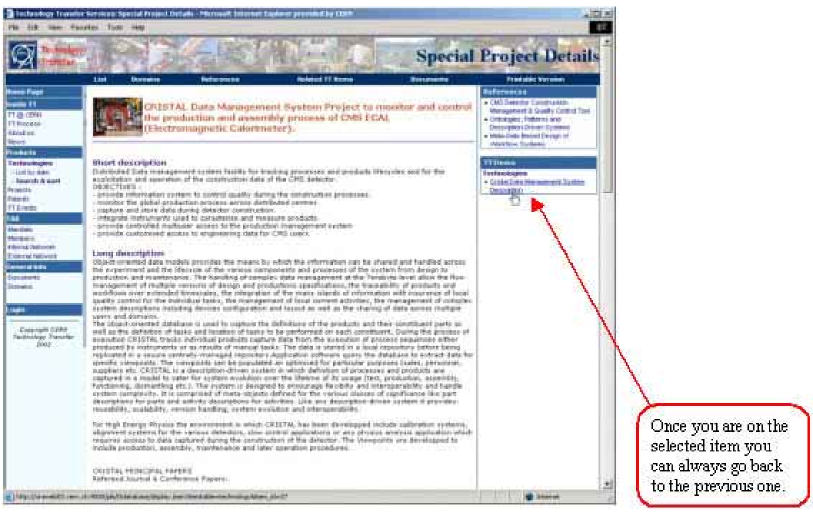


Fig. B.13: How to get details of a related TT item.

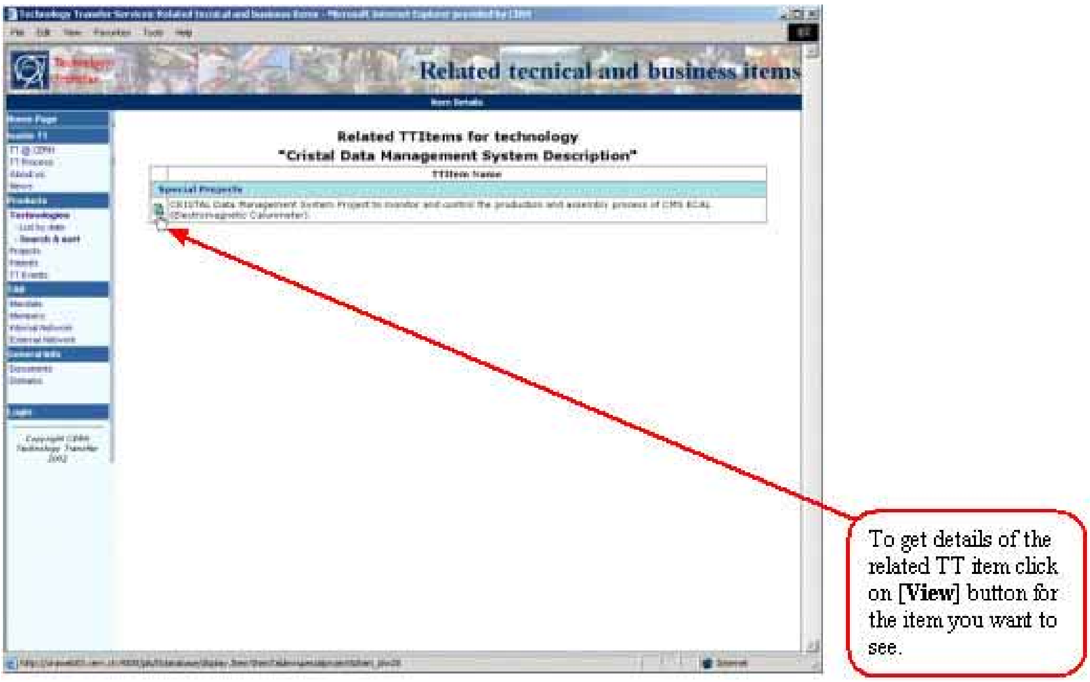


Fig. B.14: How to get details of a related TT item.

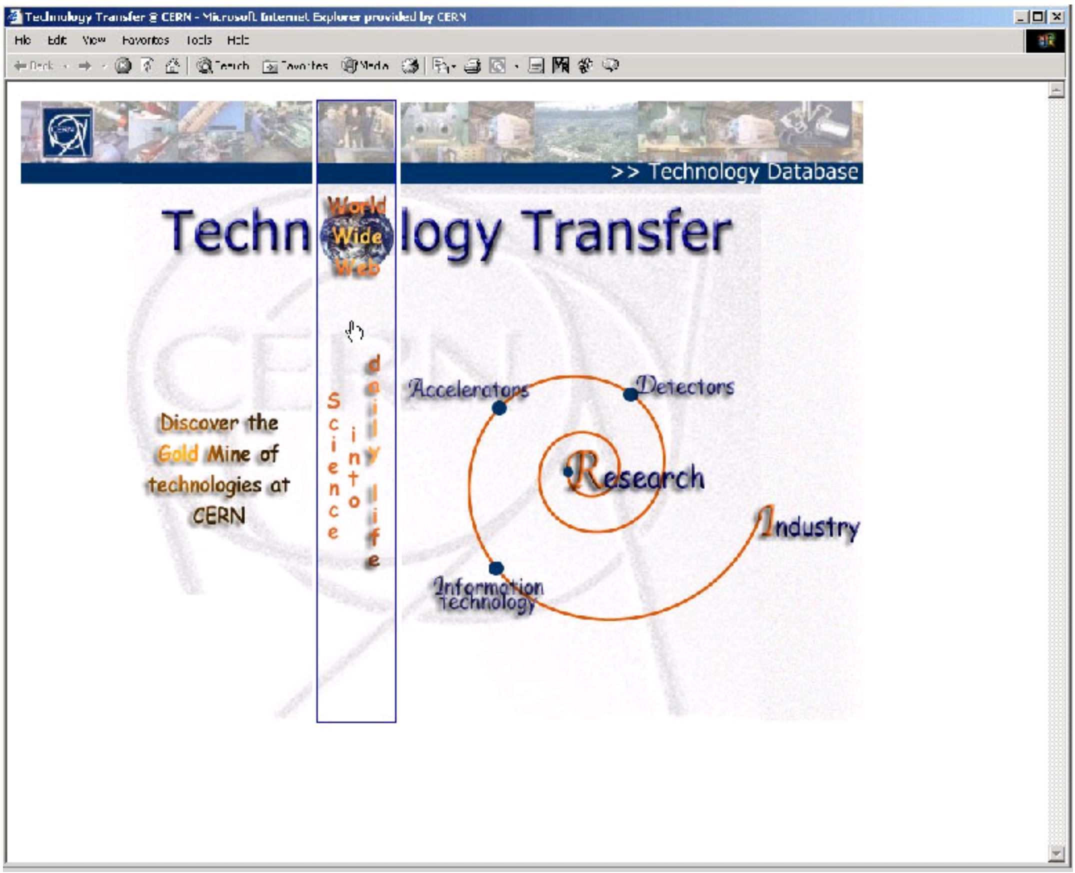


Fig. B.15: TT database home page for general public.

Appendix C: Covering letter

Geneva, 15 September 2000

My name is Beatrice A. Bressan and I am doing a Ph.D. at the University of Helsinki in the framework of the CERN Doctoral student program (http://cern.web.cern.ch/CERN/Divisions/PE/HRS/Recruitment/students.html)

For my research study (http://itlopc03.cern.ch/PhDFinland/DraftTHESIS.html) I have to carry out interviews with the past and present Finnish users at CERN to evaluate the impact of their stay at CERN on their further professional developments. I have therefore prepared the attached questionnaire http://itlopc03.cern.ch/PhDFinland/questionnaire.html and I would very much appreciate if you could fill it in and send it back to me. Please, if you wish to add comments or adapt the questionnaire to your personal case, use the empty place available for this purpose. This is the first attempt to make such an analysis and I will probably contact you again later to complete the information. If your address is due to change in the near future, I would be grateful if you could let me know.

Thanking you in advance for your collaboration,

I remain, sincerely yours

Beatrice A. Bressan

ETT Division, CERN

Appendix D: Questionnaire

nation ◯ I ◯ F | 13:38:32 | 07 September 2000

Last name

First name

Date of birth | Sex ◯ M ◯ F

Contact address
☐ Work
☐ Home

Present and past positions after leaving CERN (Please, if possible specify the years)

Tel. | Fax | P.O. box

E-mail

Activity fields at CERN	Affiliation, if different from CERN	CERN Division, Experiment and / or Group	Direct Supervisor	date	Status (Please, mark all positions held at CERN)*

* 1) ADMI: Administrative Student / 2) CASS: Corresponding Associate / 3) CFEL: Corresponding Fellow
4) DOCT: Doctoral Student / 5) FELL: Fellow / 6) PDSA: Paid Scientific Associate / 7) PDAS: Paid Associate
8) PJAS: Project Associate / 9) STAF: Staff Member / 10) SUMM: Summer Student / 11) SURV: Survey Trainee
12) TECH: Technical Student / 13) UPSA: Unpaid Scientific Associate / 14) UPAS: Unpaid Associate
15) USER: Temporary User coming from other laboratory / 16) USSA: Unpaid Associate with daily allowance
17) OTHER

Summary of main study or studies made at CERN

	TEST	ANALYSIS	DEVELOPMENT
COMPUTING			
ELECTRONICS			
MECHANICS			

Summary of main study or studies made at CERN

	TEST	ANALYSIS	DEVELOPMENT
MATERIAL SCIENCES			
ACCELERATOR TECNIQUES			
OTHERS			

Publications from your stay at CERN

(Please, attach list of main publications from the work carried out at CERN)

1) Your most important contribution from a technical or scientific point of view

(Please, quantitize from 1 to 5 - max - the level of interest)

PHYSICS	ENGINEERING	FINANCE & ADMINISTRATION
Research ☐	Vacuum ☐	Administrative support ☐
Theoretical physics ☐	Superconductivity & Cryogenics ☐	Purchasing ☐
Applied physics ☐	Accelerator ☐	Finance & Administration ☐
Electronics ☐	Material science ☐	
Software & Computing ☐	Technical support ☐	
R&D Project ☐	Mechanics ☐	
	Electronics ☐	

2) Acquired Knowledge

(Please, specify fields and subjects and if they have technological innovations outline them)

3) Topics

☐ Theoretical physics	☐ Languages
☐ Experimental physics	☐ Communication (e-mail, conferences, etc.)
☐ Computing	☐ Science communication
☐ Technical fields	☐ Organizational and/or managerial aspects
☐ Financial aspects	

(Please, give a brief description for each field mentioned above and specify contents for the work carried out while at CERN)

4) List the field of interests developed or topics studied by interacting with colleagues at CERN or outside CERN during your stay

5) Which one of the above have you put into practice after your stay at CERN

6) Which one has proved the most useful?

7) Impact of working in an international environment
(Please, cross the relevant for you)

- ☐ Discussion with colleagues
- ☐ Living abroad
- ☐ Scientific point of view
- ☐ Cultural broadering aspects
- ☐ Training
- ☐ Planning

8) Impact of training
(Please, cross the relevant for you)

- ☐ Summer student lectures
- ☐ Seminars
- ☐ Academic Training
- ☐ CERN Education Service Training

9) Which lectures have impressed you most?

for skill acquisition

for general interest

Why?

10) Which skills did you expect to develop or acquire but were unable to?

EDUCATION	TECHNICAL SKILL
Why?	Why?
MANAGEMENT	COMMUNICATION
Why?	Why?

11) Did the multicultural aspects of CERN influence your career development?

YES / Why?	NO / Why?

12) Which fields or subjects did not meet your expectation?

Why?

13) What did you consider negative?

Suggestion for improvement:

14) What was most important for your personal development?

15) Which technology acquired or skill improved while at CERN has had the greatest impact on your carrier?

16) Participation to R&D project

○YES ○NO

17) Was there any technological return or applications you are aware of?

○YES ○NO

If yes, what was that? In which area?

18) Positive or negative experience from meetings

GENERAL MEETINGS	COLLABORATION	DIVISIONAL OR GROUP	PROJECT
Illustration of subjects: ○p ○n	Illustration of subjects: ○p ○n	Illustration of subjects: ○p ○n	Illustration of subjects: ○p ○n
Definition of problems: ○p ○n	Definition of problems: ○p ○n	Definition of problems: ○p ○n	Definition of problems: ○p ○n
Work organization: ○p ○n	Work organization: ○p ○n	Work organization: ○p ○n	Work organization: ○p ○n
Management: ○p ○n	Management: ○p ○n	Management: ○p ○n	Management: ○p ○n
Time-schedule: ○p ○n	Time-schedule: ○p ○n	Time-schedule: ○p ○n	Time-schedule: ○p ○n

←

19) Outline the difference between actual working experience and CERN experience for the learning process acquisition by giving an evaluation from 1 to 5 (max.)

ACTUAL WORKING EXPERIENCE		CERN	
Managerial		Managerial	
Scientific stimulation		Scientific stimulation	
Financial consideration		Financial consideration	
Multicultural aspects		Multicultural aspects	

20) Have you obtained a position thanks to the experience acquired at CERN?
(Please, comment)

21) Had your stay at CERN an infuence on cultural interest outside your Country of origin?

Holidays: ◯ yes ◯ no

Language: ◯ yes ◯ no

Food habit: ◯ yes ◯ no

Sport and hobbies: ◯ yes ◯ no

Please use this place, if you wish to add comments or adapt the questionnaire to your personal case

Appendix E: FileMaker databases

E.1 How to built the Finns FileMaker database

A database is information grouped together in order to organize and analyse the information in a different ways. There are several steps to creating a database:

1. plan the database,
2. define fields,
3. create records, and
4. enter information.

Considering the type of information available and deciding how many files and fields are necessary is the first step to think of and organize on paper. All information available collected on the 411 Finns in the CERN archive has been classified into categories and inserted in the Finns database created on FileMaker Program, version 4.0. Fig. E.1 displays a typical record form of the Finns FileMaker database. Each record has information such as ‘name’, ‘sex', ‘date of birth’, ‘address’, ‘type’ and ‘number of CERN contract’, ‘CERN division’ and ‘group’, ‘CERN contact’ and ‘presence in the CERN electronic database’. Each piece of this information is stored in a field inside the record. For defining the fields it is necessary using the ‘file’ menu at the bottom of the screen and clicking on ‘define fields’. It is important to choose the field type based on the type of information and create the different fields typing the name of them in the ‘Field Name’ box and clicking on ‘create’ button. To click on the ‘Done’ button (Fig. E.2) is the final step for defining the fields

In order to determine how to present information, a layout structure is available for the records using the ‘mode’ pop-up menu at the bottom of the screen (clicking on ‘layout mode’), and entering the data in the different records (clicking ‘browse mode’). FileMaker programme provides a standard layout to prepare the envelope labels for letters. Therefore, by a specific find request (clicking on ‘find mode’) it is possible to select a group of records for making same statistical consideration on this selected group.

To be in ‘layout mode’ permits to format a field to display a value list (pop-up list, pop-up menu, radio buttons or checkboxes). For example, to format a field to contain two radio buttons (‘Presence in CERN database’, ‘yes’ or ‘no’, Fig. E.1) the procedure is: to select the correspondent filed, to choose ‘Field Format’ from the ‘Format’ menu at the bottom of the screen, to select ‘Pop-up list’ from the ‘Standard field’ and to choose ‘Define Value list’ from the pop-up menu. When the field displays the sales regions: type ‘Presence in CERN database’ in the box ‘Value list name’ and to click ‘Create’. To define values for the list the procedure is to click on ‘Use custom values’, to type in the correspondent box ‘yes’, press ‘Enter’, type ‘No’, click ‘Save’ and then ‘Done’.

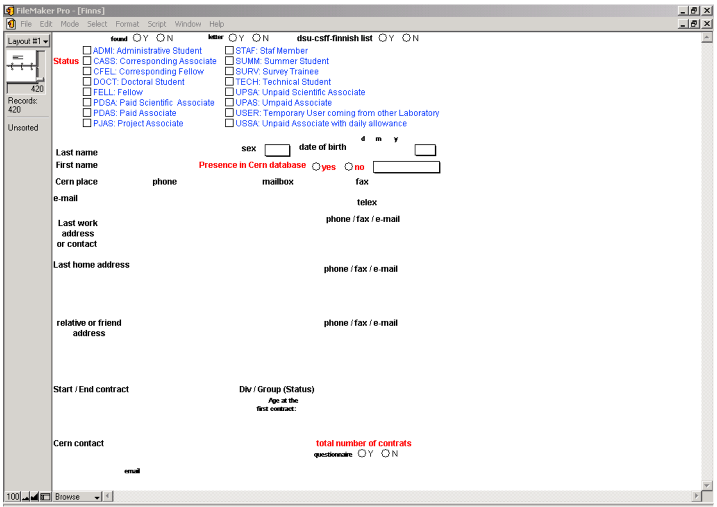


Fig. E.1: Record of the Finns FileMaker database.

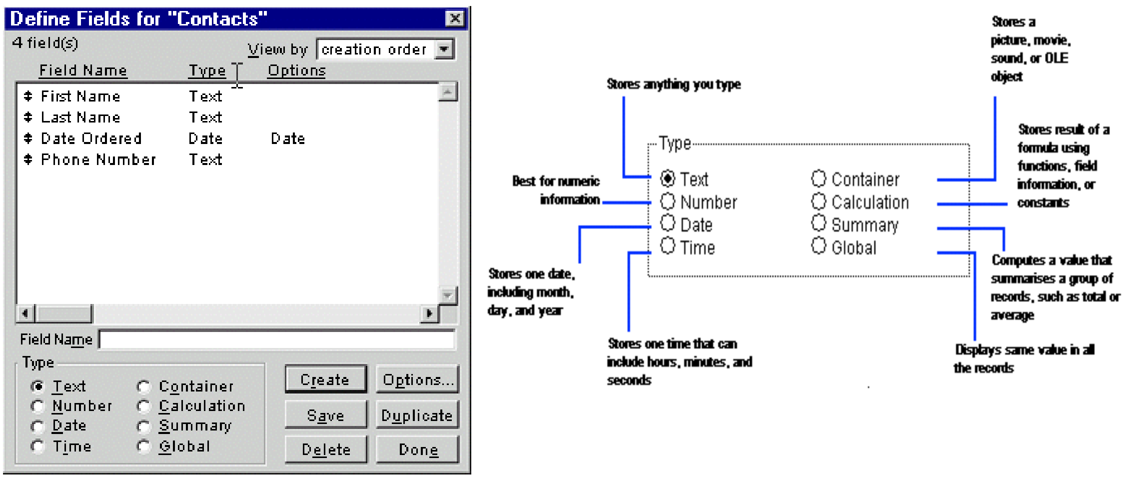


Fig. E.2: Field definition and types.

The steps to establish the way in which the value list must appear are choose ‘Radio Buttons’ from the ‘pop-up list’ and click ‘Ok’ in order to return to ‘Layout mode’. To test the value list it is necessary to be in ‘Browse mode’ (Fig. E.3).

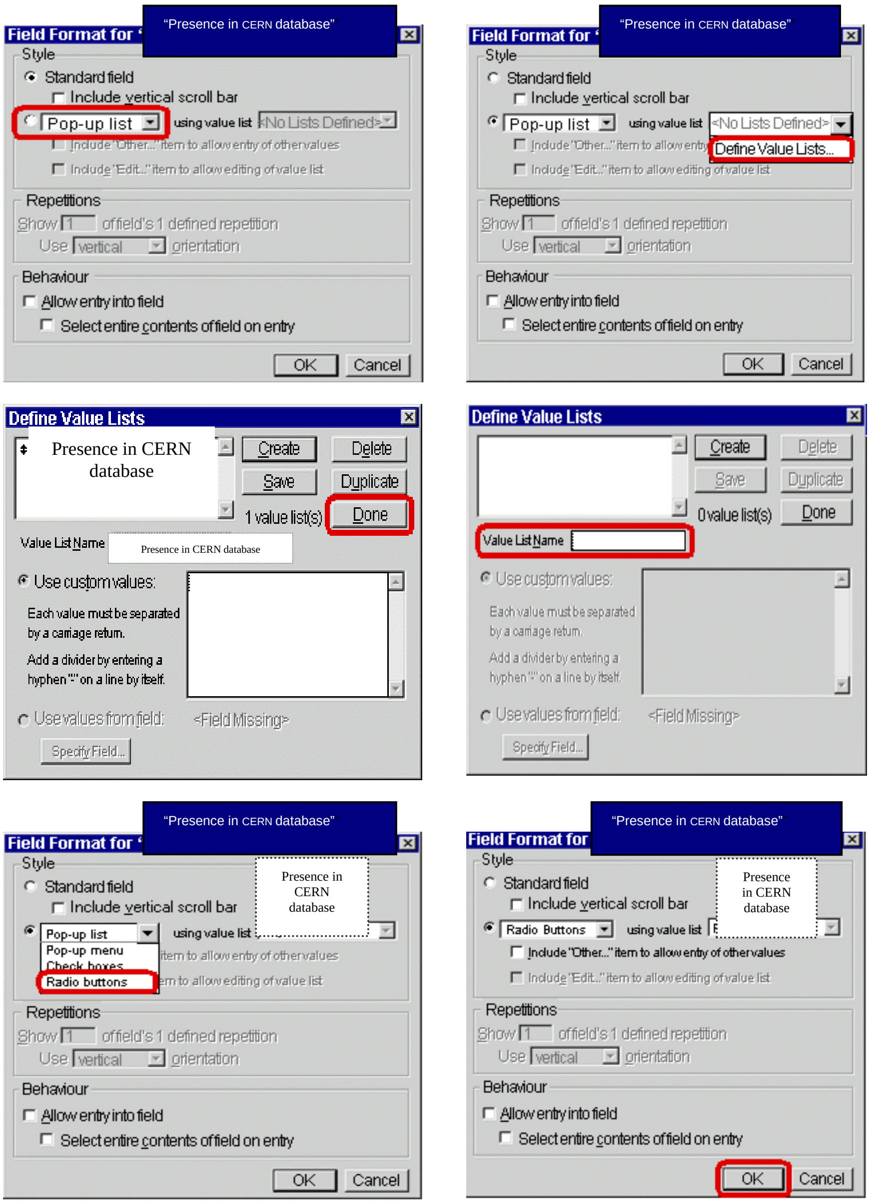


Fig. E.3: How to format fields to display lists of predefined choices.

E.2 How to link the FileMaker database to the Web questionnaire

The questionnaire in HTML published on the Web has been prepared with the same fields and characteristics of the questionnaire on FileMaker. Two tasks have been performed to permit users to access data in their Web browsers. The first is to enable the Web Companion plug-in (once enabling the Web Companion, Web sharing is available for any open database) and the second is to enable Web sharing for each database to publish on the Web.

The procedure for enabling FileMaker Program Web Companion is:

1. Choose 'Preferences' from the 'Edit' menu and choose 'Application',
2. Click the 'Plug-Ins' tab in the 'Application Preferences' dialog box,
3. Select the 'Web Companion' checkbox,
4. Press on 'Configure' button to set the default settings (Fig. E.4):
   4.1 Instant Web Publishing is enabled.
   4.2 The Built-in home page generated by the Web Companion is used.
   4.3 English is set as the language for the Web browser interface.
   4.4 No Web activity log is kept.
   4.5 Remote administration of Web databases is off.
   4.6 Databases you publish are protected by standard access privileges.
   4.7 The TCP/IP port number is set to 80.
5. Click 'Ok' to return in the Application Preferences dialog box, and
6. Click 'Done'.

The procedure for publishing each database on the Web is:

1. Choose 'Sharing' from the File menu,
2. Select 'Single User' radio button,
3. Select the 'Web Companion' checkbox in the Companion Sharing area,
4. Click 'Ok'.

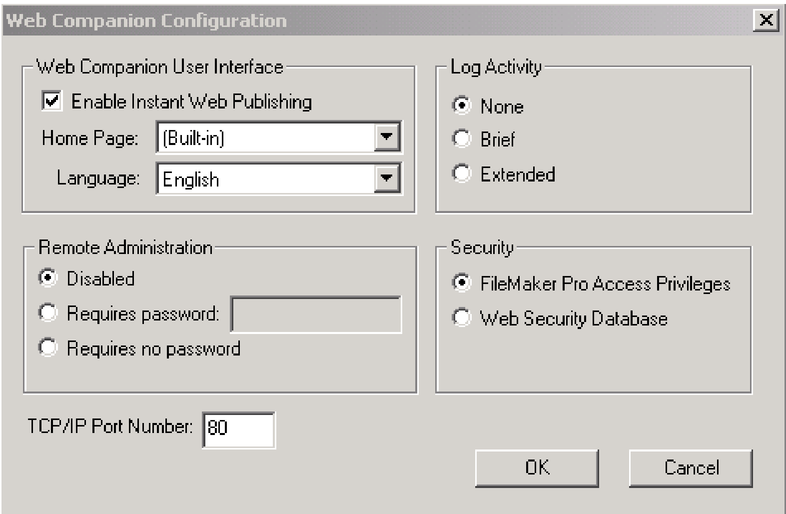


Fig. E.4: Default settings of the Web Companion configuration.

To create the link between the FileMaker database and the Web questionnaire, it is necessary to put the Format files used in Custom Web Publishing (including the questionnaire on FileMaker database) in the 'Web' folder in the FileMaker Program folder, with the instruction 'Web Companion' activated.

Appendix F: An example of how to communicate technology

A look at the Large Hadron Collider, the next accelerator of CERN, the European Laboratory for Particle Physics located on the Swiss–French border near Geneva

Technology: Injection of Science into Daily Reality

How and when did research begin to affect your life?

by Beatrice Alessandra Bressan

What is the LHC? A particle physicist will answer: “The Large Hadron Collider, the future circular particle accelerator of CERN, the European particle physics laboratory in Geneva.” To clarify ideas he would add: “ It is a machine which can give us a much greater understanding of the Universe.” Someone from other domains would answer: “I haven’t a clue!” Trust me. That’s already closer to the right answer. Because the LHC is much better than any answers you can imagine: it is the next step in a voyage of discovery into a ‘gold mine’ of technologies. “The LHC is a high-tech project of extreme complexity and its technical foundation is rock solid,” – Says Luciano Maiani, Director-General of the Laboratory. “All the many technological components and programs which are working in parallel towards the successful completion of the accelerator are progressing extremely well.” Overcoming unprecedented scientific and technological challenges, LHC may change daily life beyond our imagination.

Technology transfer: bringing science into daily life

Have you ever considered how technology affects our everyday lives so much that we don’t even think about it? Just consider what each day would be without technology? You wake up to an electronic alarm; brush your teeth with a technically advanced toothbrush while the coffee is getting ready and your mobile phone is ringing. You can discover the latest world events by turning on the television. What is the first thing you do when you start your day at work? You sit in front of your computer and you read e-mail messages from anywhere in the world. You can have any kind of electronic relationship with anyone who affects your life. It is possible because of the broad use of the Internet and of one of its best practical implementations, the World Wide Web.

Through the LHC, which will provide data at a tremendous rate (equivalent to every person on the planet talking to twenty telephones at once), the particle physics community is poised to deliver the Web of the future, which is called the Grid. This name traces its origins back to the romance of the pioneering era when the electrical power grid was a symbol of freedom. The same freedom that the Grid will give you tomorrow in exchanging information. Thanks to this future network you will be able to plug your computer into the wall and have direct access to huge computing resources, just like you plug in a lamp to get instant light. CERN, 'where the World Wide Web was born', aims to tackle the LHC computing challenge by working with computer scientists, scientists from other disciplines, and above all industry. The future accelerator makes the Laboratory the ideal test-bed for the Grid, but particle physics is not the only field facing a data explosion. Bioinformatics, with its vast quantities of genome and gene expression data, space physics, satellite earth survey, and astrophysics are also on the crest of a growing data-wave. But for the time being, the LHC's immediate requirements for major distributed collaborative work and resources are unique. The Grid represents a new vision of computers and networks and will bring together, in particular, researchers from biological science, earth observation and high energy physics, where large-scale, data-intensive computing is essential. The computing Grid shares the pioneering spirit, transferring it to a distributed grid of computing resources in which supercomputers, processor farms, disks, major databases, information, collaborative tools and people are linked by a high-speed network.

Why has CERN always been in the vanguard of computing and networking technology? CERN is the world's largest physics research laboratory with over 50% of all active particle physicists in the world participating in more than 100 different research projects. In addition, there are about 2700 staff members as well as 300 students and fellows supported by the Organization. There are more than 6000 visiting physicists, engineers and computer experts from 80 different countries and 500 scientific institutions, specialized in technologies and collaborating with the laboratory. Binding together the creativity of so many different nationalities, backgrounds and fields of research, allows the creation of the best environment for scientific ideas to become technological reality. “Scientific research lives and flourishes in an atmosphere of freedom — freedom to doubt, freedom to enquire, and freedom to discover”, as Sir Ben Lockspeiser, the first President of the CERN Council, wrote in 1954.

How did this all come about? “As usual, in the beginning was chaos,” said Robert Cailliau, who together with Tim Berners-Lee wrote the first part in World Wide Web software. “In the same way that the theory of high-energy physics interactions was itself in a chaotic state up until the early 1970s, so was the so-called area of data communications at CERN. The variety of different techniques, media and protocols used was staggering; open warfare existed between many manufacturers' proprietary systems, various homemade systems, and the then rudimentary efforts at defining open or international standards.” Let’s look at the history of Internet, conceived to put the universe in communication with you. The Internet itself was born at the crossroads of the computer and telecommunication industries. On 4 October 1957, the USSR launched Sputnik, the first artificial satellite to successfully orbit the Earth, causing the development of space technology to become a national priority in the U.S.A. and marking the beginning of global communications. Between 1962 and 1968, Packet-Switching (P-S) network technology was developed to transform secure data into tiny packets that could take different routes to a destination. The birth of the Internet, namely the technical infrastructure consisting of a global network system, was in 1969 with the first node at University of California, Los Angeles. However, it would have been impossible to benefit from the advantages of the Internet without the research completed at CERN in the last decade of the twentieth century when the World Wide Web came into being. “The World Wide Web has broken any limits for any words’ cross connection,” says Gregory R. Gromov, Founder, Editor and Publisher of Internet Valley in Sacramento, California. The reason why it was really possible is because “the network is not a computer science concept but a linguistic concept”, said Alberto Cavicchiolo, President of the European Virtual Bank, sited in Milan, Italy. Indeed, the Web was originally conceived and developed to provide a common method to distribute information across the world from any desktop computer for the large physics collaborations which demand instantaneous sharing of information amongst physicists working in different universities and institutes. Understanding immediately its importance and profiting from its research scope, industry positively influenced the acceptance and spread of Internet technologies in Europe and elsewhere. In 1977, e-mail took off and that is when information technology started to impact on our daily lives. At the end of the 1980s the Web was CERN's response to a new wave of scientific collaborations. As those collaborations reach their conclusion CERN is preparing a new scientific instrument, the LHC, for a new generation of experiments. To date, the computing requirements of the LHC's experimental collaborations are unprecedented, far exceeding those of other fields of science or branches of industry and commerce. So, 1999 was the time to start thinking of the Grid!

It is easy to see how the Internet and the Web have influenced our day-by-day reality. Other technologies have a significant though less visible impact. Many are the technologies which have been developed in the course of research activities at CERN that have lead to industrial and medical applications. Particle physicists regularly use collisions between electrons and their antiparticles, positrons, to investigate matter and fundamental forces at high energies. Maybe you think that this does not concern you at all, but let us see how these can affect your daily life. When an electron and a positron meet they annihilate, turning into energy what, at high energies, can again materialize as new particles and antiparticles. This is what happened in machines such as the Large Electron Positron (LEP) collider. At low energies, however, the electron-positron annihilations can be put to different uses, for example to reveal the functioning of the brain in Positron Emission Tomography (PET). One of the first PET images was made at CERN in 1977 using devices specially developed for high-energy physics. Exactly twenty years later, the Crystal Clear collaboration, set up in 1990 to develop scintillating materials suitable for use in extremely demanding LHC applications, has developed a new fast scintillating detector ideal for PET applications.

Today PET is a new scanning technique in medical research. PET allows us, for the first time, to view in detail the functioning of distinct areas of the human brain while the patient is comfortable, conscious and alert. We can now study the chemical processes involved in the functioning of healthy or diseased human brains in a way previously impossible. Before the advent of the PET scanner, we could only infer what went on inside the brain from post-mortem examinations or animal studies. An X-ray or a Computer Tomography scan shows only structural details of the brain. The PET scanner gives us a picture of the brain at work. Now, thanks to the improvements of these technologies, PET represents a new step forward in the way scientists and doctors look at the brain and at how it works.

Recently these techniques have been applied to visualize on-line the spatial distribution of a hadrontherapy dose, an advanced method of radiation therapy to treat deep-seated cancers, which employs beams of carbon ions.

Even if you recognize immediately some technical aspects in the electric household, you cannot imagine the high level of technology hidden behind every apparatus you contact over the day. Every cathode-ray tube used in TV sets and computers, lamps, or in industrial and scientific applications, make use of very high vacuum technology. Many technologies are involved in creating and maintaining vacuum. One of them, invented and developed at CERN over the last ten years, uses getter devices: special alloy-based components. "Thanks to a property well known since the nineteen century," says Cristoforo Benvenuti, the physicist who designed the pumping system of LEP, "when introduced in a vacuum system, the getters react chemically with the molecules of the residual gas. In this way these molecules are fixed on the surface of the getter, increasing the degree of vacuum. In high energy physics these materials are used to improve the vacuum in particle accelerators. For the LHC, CERN has recently developed an innovative and refined technology, easily transferred to industry, which allows the entire internal surface of the accelerator vacuum chamber to be covered transforming it into a pump." Vacuum technologies can be applied in different domains. According to the regulations for the 'greenhouse effect', the use of vacuum technologies can improve the thermal isolation in the electric households appliances (especially refrigerators and ovens), minimizing the relative thermal emission. Another application could be in thermal isolation of buildings, reducing the thickness of walls and windows. Another possible application concerns the 'flat panel display' in which it is very difficult to achieve a good vacuum. Indeed, these flat panels need many different fix points emitting electrons by activation in order to scan the image, unlike the electron pencil beam of the traditional TV display. Vacuum technologies can be applied not only to save energy but also to produce energy in high efficiency solar panels. One can imagine of replacing the expensive catalyst used in the 'hydrogen fuel cell' by cheaper getter materials.

But that is not the end of the story. Are you aware of a technology called 'hood clamshell tool'? It is another vacuum technology, developed and patented two years ago, for the inspection of the LHC magnets. In particular it is a device based on hood methods to test leak-tightness of vacuum systems. This method consists of a leak detection device in which a metallic casing encloses the vessel under test so that a high accuracy dynamic leak test may be carried out on a large portion of the external surface. The system is especially suitable for areas of restricted access and where pipes are extremely long. The device can be quickly installed and used by a single operator, incurs no risk of joint pinching, can be used on pipes of two different diameters and over a wide range of pipe dimensions (from 30 to 300 millimetres). Because of these numerous advantages this technology can be applied in many different fields outside physics: in vacuum tightness for all installations and pipe work, in electronics and in cryogenics laboratories. It can be also used in production plants, for the transport of hazardous and natural fluids, and in medical, food and agricultural applications.

The study of LHC magnets behaviour in function of the temperature brought another revolutionary thermometry method based on use of optical fibres. "Thanks to a phenomenon knew as 'stimulated Brillouin effect'", says Walter Scandale, the author of this discovery, "with an appropriate calibration the optical fibres become thermometers for measuring very low temperatures. Besides the economical aspect, the best advantage is the feasibility to measure the temperature along all length of the apparatus instead of at a specific point. " It seems unimaginable, but you can find applications of this singular effect even in the transport sector.

In particular, 'Swissmetro' is a realistic example that will use many of the technologies described above. It is a very innovative Swiss train: it is a high-speed and high-frequency passenger transport system working as a super underground railway independent of built-up areas and surface obstructions such as topography. The Swissmetro system is based on the use of four complementary technologies: an entirely underground infrastructure, a reduction of pressure in the tunnels (partial vacuum corresponding to the pressure at the altitude at which Concorde flies) in order to save the energy necessary for the propulsion of the pressurized vehicles, a propulsion system made of linear electric motors; and finally a magnetic levitation and guidance system.

There are no limits to the infinite possibilities offered by the ‘wonderful land’ of technology. Technology represents on all levels the injection of science into our daily reality. Thanks to the technologies developed for the purpose of its research activities, CERN has not only reduced the existing technological difference amongst the main developed countries, but has also, thanks to its scientists finding better solutions to technical and scientific problems, benefited humanity. Through technology, CERN research has increased not only our knowledge but also succeeded in making our daily environment more functional, practical and comfortable. Scientists know what Winston Churchill meant when he said: “Success is never final, and failure is never fatal”. So, science goes on…

See: http://www.cern.ch/TechnologyTransfer/