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Original article

Communication in the work of professors and researchers: a study on physicists' activities

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Abstract

The reflections in thist article result from a study on the work activities of professors and researchers in a Brazilian public university. The study analyzed how the academic teaching is organized from an ergological perspective, considering the approaches found in activity-centered ergonomics, sociology of science, psychodynamics of work. A basic science institute (the Physics Institute, henceforth referred as PI) was chosen as the scenario for the analysis of the work dynamics of professors and researchers. The article describes some aspects of professors'/researchers' activities and communication-related factors found in the scientific-academic activity and draws attention to their complexity.

Keywords

scientific communication; work networks; academic production; uses of oneself; organization of scientific work

This article discusses some features of communication in the academic work. The issue was addressed in a doctoral thesis presented to the Committee of Graduate Programs in Engineering, Instituto Alberto Coimbra, COPPE/UFRJ, funded by Capes-Brasília and published as a book in 2004. The dissertation depicts the practice of the inseparability principle by professors/researchers, that is, it explores, in detail, how they perform their teaching, research and extended learning activities. One of the hypotheses of the study was that the criteria adopted by the appraisal system of university professors/researchers prioritize one of the elements of the inseparability principle (scientific research) over other elements. The main objective of the study was to collect data to contribute to the debate on the appraisal of teaching and research work by observing what activity-centered ergonomics considers as "real work" in scientific research and teaching.

Focus was placed on an institute of basic science within the university context. Such choice is justified by the fact that investment priority is given to basic science in several countries and, as a research area, Physics boosts engineering-related multifaceted industries (software, equipment, electronics, chemistry, etc.) while developing its activities. One example of this phenomenon is the field of Elementary Particles, which requires extremely accurate equipment from different areas to conduct its experiments and fosters, as a result, the development of a large supply network on technology, comprised of engineering companies, electronic equipment manufacturers, software engineering business etc. Necessities arising along the research process are later developed into technological applications. One example is the construction of the tunnel connecting France and England under the English Channel, which used know-how acquired in the construction of the CERN[1] laboratories in Geneva, one of the world's largest particle accelerators. Another well-known example is the WWW information flow protocol. It stemmed from the need for scientists working in different countries to communicate, and was later applied to Internet. As a consequence, the work of scientists is linked to a network of relationships that go beyond the realm of universities and research institutes (CANGUILHEM, 1972; RIP & GROENEWEGEN, 1988; SCHWARTZ, 2000a; ALVAREZ, 2004).

This article will not focus on the issue of scientific appraisal, which was addressed in the thesis. Rather, it will discuss some communication aspects found in the organization of the work done by the physicists in the above-mentioned university. It should be noted that communication is understood here as the occurrence of permanent and heterogeneous dialogues, the use of oneself by oneself and by others – which evoke background that is developed within the practice of the twofold job researcher-professor. Thus, these dialogues surface at the level of activity and evoke debate on values. On a daily basis, these values appear in the work routine of professors and cause them to make decisions that are not always easy. Ergological practice penetrating epistemological knowledge produces displacement which causes intellectual discomfort (SCHWARTZ, 2000).

They are necessary dialogues found in the organization of the teaching activity, indicating unique forms of communication. One example is realizing that two distinct functioning systems coexist in the organization of work at universities: one concerning research-funding agencies and one concerning the university structure (which encompasses teaching, research and extended learning). Another example is when a particular way of forming groups – *colaboration*[2], which are frequent in the area of Elementary Particles - implodes, to some extent, the main criteria to assess productivity (number of articles published) as defined by funding agencies.

Similarly, work organization requires a network setting and characterizes the relation among several unique and extended work collectives. When some features found in the academic work are identified, unique forms of communication are found to pervade those different dialogues. What is specific about the organization of academic work and its forms of communication? Which features can identify them? This is what this article aims to map out.

Methodology and methods

The theoretical framework on which this study is based favors the following fields: Activity-centered Ergonomics (DANIELLOU, 2004; GUÉRIN et al., 2001; WISNER, 1994), Sociology of Science (LATOUR, 1997, 2000; CALLON, 1997, 1988), and Psychodynamics of Work (DEJOURS, 1991, 1993). However, in order to widen the scope of the debate it proposes, this article also reviews authors that are not strictly connected with those fields. Other types of framework complement the study, aligning knowledge from both science and practical experience which are relevant to the analysis of work-related situations as proposed by the ergological perspective (SCHWARTZ, 2000; 2007).

The methodological contributions made by the above-mentioned approaches contribute to bridging the gap between the actual work and the reality of work and, hence, between the discrepancy of the prescribed dimensions and the actual accomplishments. This happens, to a large extent, by means of indirect methods, that is, workers participating in discussions, the experience they have gained over the years being valued, their attributes being associated to the share of knowledge that surfaces in the course of activity. This way, the methodology used was based on the Ergonomic Analysis of Work (EAW) in the steps concerning demand analysis, overall data collection, general and systematic observation, validation. Data collection took place by means of interviews, conversations, observations and verbalizations.

Systematic observations were made upon a group of the ATHENA project, at CERN – Laboratoire Européen pour La Physique des Particules, at UFRSM – *Unité de Formation et Recherche des Sciences de la Matière, at the Université de Provence and at Laboratoire des Ondes Acoustiques, at EPCI - École de Physique et de Chimie Industrielles* and in the three integrated research groups at the Physics Institute (PI): one devoted to experimental research; one conducting theoretical research, and one comprised of people from different departments and different research groups that develop extended learning activities. The groups were selected based on the following criteria for the members: (1) they should be professors/researchers currently involved in research; (2) they should be receiving grants from CNPq (National Council of Scientific and Technological Development) to do research; (3) they should teach in undergraduate and graduate programs on a regular basis; (4) they should advise students in graduate and/or young researchers programs.

Familiarizing with the university as a whole involved learning about the infrastructure, the facilities and human resources of the Physics Institute and consisted of the following actions: visiting the PI premises; participating in two faculty meetings; interviewing technical and office staff, directors and assistants; attending laboratory activities, group meetings, classes taught by research coordinators and refreshment courses for high school teachers (one of the extended learning activities conducted by the PI). Group leaders were interviewed according to a script, aiming to map issues regarding (1) the importance of introducing research into the university; (2) the significance of extended learning in the field they work in; (3) the existing relationship among the three items that comprise the inseparability principle (teaching/research/extended learning); (4) their views on the appraisal of research activity; (5) the definition of project, product and productivity in their field; (6) the type of funding they receive and (7) the features of the work they develop. The group members answered a questionnaire and participated in a group interview. It should be noted that the script aimed to provide the researcher with orientation and foster dialogue rather than limit the participants' spontaneous contributions. It is also worth of notice that a purely "neutral" research cannot actually be done, as there is the need for a "starting point" stemming from theoretical and methodological references that guide the researcher and narrow down the focus of the study as a human activity.

The observations were followed by self-confrontations and validations:"règles de *métier*"(TEIGER & LAVILLE, 1989). Group discussion of the results of the study and their possible treatments – by means of a scientific article and a talk targeted at the scientific community from the PI - were used as a self-confrontation resource. Such devices enabled the investigated community to confront the concepts designed from the systematic observations. They also contributed to the study by allowing room for interaction and discussion in the Institute. Thus, it was possible to put into practice both the methodological principles of EAW and the principles adopted by the three-pillar device proposed by Schwartz (2000).

The context: what a professor/researcher does at the Physics Institute

The scientists investigated in this study work at the experimental laboratories, and do a wide range of activities: they design, assemble and repair equipment; create computer software; deal with electrical fittings; discuss solutions with technicians from different areas; request quotes; resolve problems at customs; design projects and negotiate with research-funding agencies; write reports; render accounts. They perform their job in a technical environment which is full of material constraints.

In their turn, the scientists who are involved in fundamental research create computer software; become regularly acquainted with the latest information; discuss relevant issues with their colleagues; design and negotiate projects with research-funding agencies; write reports and render accounts What current material conditions are available in each particular situation for a scientist to do his intended job? In the PI, professors/researchers deal with several constraints: lack of funds in the departments and laboratories; bureaucratic red tape involving the purchase of materials and instruments; customs-related drawbacks to importing equipment; problems in the infrastructure of the laboratory premises; breakdowns in computer networks; faulty telephone network; changes in research-funding policies. Another major constraint is the low remuneration and lack of incentive to continuing education opportunities for the laboratory technicians, resulting in dissatisfied technical and office staff. The whole functioning or disfuntioning apparatus is put into practice to manage the daily variability that each laboratory is faced with while 'doing' science. Moreover, research is not the only activity taking placing at the university; knowledge is also produced by means of teaching and extended learning.

Some features of the organization of academic work

The academic work relates to hierarchy in a unique manner; it functions according both to the administrative and bureaucratic structure of the university and the research-funding agencies'. It is organized as a network (comprised of research groups).

The hierarchy observed in research groups adheres, to some extent, to the hierarchy of the academic career, as groups are made of professors holding different positions in the career plan: assistant, associate and full professors. Participants that are student researchers include those in young researchers' programs and those pursuing master's, doctor's and post-doctorate degrees. Attendance to group meetings and laboratory measurements showed that division of tasks occurs between young researchers and experienced researchers. In addition, there are moments when the academic hierarchy was almost diluted, giving way to common fruition and a blend of competencies where long-term experience does not predominate. A shift in hierarchy actually takes place, as the students presented the researchers with knowledge that the latter were not familiar with.

The researchers/professors constantly adjust between the two systems to enable the accomplishment of their activities. They cope with at least two different organizational structures on a daily basis: the university structure and the research structure. As professors, they are associated with the university – the rector's office, the centers and the institutes, the programs, the departaments – that is, the whole administrative structure of the university, encompassing its councils, comissions, assemblies, positions, hierarchies.As researchers, they are associated with funding agencies (CNPq, Capes, FUJB, Finep, Faperj) and their own research center. Each above-mentioned institution has its own operational features, norms, rules, values and objectives. They are fields that constantly overlap and, thus, bring different types of difficulty which have to be resolved by the professionals working in them. In order to reach their goals, researchers have to be familiar with the two operating structures, follow their rules, volatile prescriptions and regular practices, as well as keep track of their changes, paths and shortcuts. That is a requirement to professional growth and survival in the field. Another unique feature of a university is that it is configured in research groups that blend these two operational structures.

What research groups are

The university structure – with deanships and departments – does not directly influence the way whereby research groups are formed. Their projects are submitted to CNPq and research-funding agencies regardless of whether or not the group members work in the same department, institute or center.

Vidal (1995) sees an integrated research group as a structure centered around one or more research leaders, comprised of full and associate professors, master and doctorate programs' students, and young researchers who have converging research object and objectives, share similar views and depart from the same theoretical framework. The basic activities of a group are action, production and reflection. The outcome of such production can be shared with other groups that will compose the "nodes" of the social network where sharing among researchers actually takes place.

The Research Group Directory of CNPq (1995) listed 18 research groups in activity at the PI at the time this study was being conducted. Martins and Galvão (1994) define the Directory as a database that offers updated information on people and methods of research being done in Brazil in the fields of science and technology. The very first contacts with the researchers from the PI revealed that the groups are heterogeneous: some groups have few members while others have many; some focus on experimental research whereas others deal with theoretical research, while others do both types; some have little experience as opposed to others with over 30 years of research experience. Another relevant feature of the groups at PI is the partial turnover of its members – the graduate students – who might leave the groups as they finish their thesis and dissertations and defend them before the assessment committees. The Physics Institute also has groups solely composed of researchers. This is a seasonal situation taking place when the professors have no advisees – an increasingly common situation in the area of physics because there are not enough scholarships and incentives to careers in research.

There are two major research areas within Physics that interact and complement each other: Experimental Physics and Theoretical Physics[5]. Very different types of groups focusing on these two areas are found at the PI: there are Experimental Physics groups comprised of a small number of people and basically devoted to one research area. They have little connection with outside groups. Other groups have several members and work collaboratively; a network of international relations is crucial to their existence. Groups involved in Theoretical Physics are also diverse as regards number of members and activities developed. Some have partnerships with experimental groups, while others are solely devoted to the theory. All the groups investigated, whether focusing on theoretical or experimental physics, keep national and international networks of relationships, the difference between them solely being on frequency of contact and number of members in the network.

The Experimental Physics groups need to purchase equipment and materials and use a laboratory to perform research activities. Some of the groups under study at the Physics Institute had laboratories located at the PI which they maintained as well as other laboratories located abroad and supported by other international groups. Some groups provided services and set up partnerships with other laboratories in addition to developing their own research line. The dividing line between experimental and theoretical physics was sometimes blurred because not infrequently theoretical groups interfaced with experimental groups. For example, the Quantum Optics group had an experimental phase when it developed two projects: one involving the design of an atom trap for experiments on antihydrogen at CERN (within the ATHENA project) and one aimed at producing twin photons.

Functioning modes: groups and collective work

The members of a group recognize one another so that each group node is formed by alternating subjective ties and outcomes. Whatever makes a "node" in a group should be seen as the construction of multiple meanings, a great deal of nonsense plays, of paradoxes. What are such processes of events, encounters, representations, illusions, imaginations? Encounters among people, encounters of living beings, of artifacts, tools and equipment that can exert influence and receive influence. This focus disrupts sequential thinking, which presupposes a beginning, a root, and ideas that follow from there. This idea arouses reflection upon the way professors/researchers organize themselves in work situations: a network type of organization, where the groups are the points of the network, which can be connected to other points, forming a network of relationships where there is neither a beginning nor an end.

In ergonomic studies, several terms are used to name the types of activity performed by a professional team and their communication features. Words such as coactivity, cooperation, collective activity, and work collective are widely used. They are defined by authors differently and sometimes applied with totally opposite meanings. For Barthe and Quéinnec (1999), such typological considerations are inherent in different theoretical conceptions and contribute very significantly to the study of collective aspects of human work by providing analyses that favor some aspects of cooperation over others (communication, organizational aspects, collective resolution of incidents, etc.), which result in some conceptual fluidity, however. Among the wide range of terms available, we have selected the ones that we believe to be more suitable for the study of academic collectives.

Navarro (1991) claims that the existence of a work collective implies in the production of knowledge of how such collective works, in the use of a common language and in the practical application of an interindividual regulation process. The physicists-theorists investigated in our study share a common language (operating language) - the mathematical formalism - which integrates the research groups. The experimental groups have their own language which is often exempt from the need for mathematical analysis, as the object of their work is often comprised of properties or behaviors that cannot be calculated and which generate speech based on a specific nomenclature, negotiated among the different groups, accessible to anyone with minimal experience in the field. Unlike mathematical language, which is universal, the language of experimental physics has several aspects which can only be understood by those involved in a given area. Subsidiarialy, they make some mathematical analysis, especially when they need to give data statistical treatment. Theorist physicians use several languages at work: the codes of spoken and written Portuguese; the codes of spoken and written English; the codes of computer language; the concepts and formalism of Physics which relate to a given line of research and its further developments; mathematical signs and their formalism, which have an integrating function, according to the research coordinator of the groups investigated.

> *The group is supposed to use a language, which equates to language people use to work on different things; so, a language is chosen, a language that we need. So there are about two or three formalisms, so to speak, which are required for almost all the studies we have been doing now. Formalisms are calculation techniques. In Physics and in this particular area, there is more to calculation techniques than merely a little integral, or a derivative or an addition. Sometimes it's about complicated formalism, so it takes you a few months to understand the reason for such formalism or understand some things conceptually. There are many mathematical languages, and maybe I'll understand only 1% of what another physicist says in a seminar here..*

The interindividual regulation process takes place through academic hierarchy (professors/students), through informal agreements and by means of contracts, for example those made with CERN, where operational rules, rights and duties of the involved parties are established. Courteix-Kerouf (1995) emphasizes the operating nature of forming a work group and coins the concept of the dynamic work cell, which is comprised of operators with a common mission. According to a current project coordinator at CERN, in this university, which is devoted to experimental physics, work is mainly collective because one single person cannot conduct an experiment because different types of professionals are required: some are specialists in Positron Physics while others are specialized in Antiproton Physics, others in Atomic Physics and others in Particle Physics. Different people contribute to each experiment. As regards research groups, the common mission is related to the line of research and the paths they branch into at a given moment.

Some Ergonomics theorists have given a great deal of thought to the concept of cooperation. Cooperation can be defined as "action of participating in a common task". This action can be an imposition of management, or an initiative taken by operators in the event of an incident or an increase in the workload. According to Barthe and Quéinnec (1999), cooperation can be motivated by reasons that are apparently secondary to the task, for example the pleasure in working together or working with people one likes. As regards the research groups investigated in the PI, doctorate students often said that they had chosen their advisors for admiring their reputation and achievement in their field of knowledge.

As several operators cooperate, they have to coordinate their actions at some point, so they can effectively reach an ultimate objective. Rasmussen (1991) describes different social organization structures to coordinate tasks, where only one individual can be in charge of coordinating other people's tasks, or a reverse cooperation mode where each operator locally coordinates their task with their other teams. Both types of coordination are present in the research groups.

The operations of the collective task can be performed by the teams either simultaneously or at different times, that is, as a sequence of actions. The temporal dimension to execute a collective task depends on the level of dependence of the different operations. The issue of temporal interval over the multiple subtasks of a collective task brings to surface the limit of collective work. Can we refer to collective dimension if we consider that a time interval is accounted for in several years? Schmidt (1991) believes so, and exemplifies the differential cooperation with the evolution of scientific research. He also explains that a collective task may last for several centuries in some cases.

We can thus conclude that the research groups work with two types of collectives: a singular collective comprised of people from each group who interact among themselves and with support technicians while setting up experiments, analyzing data, participating in meetings; and a larger collective where the scientific community share contributions in their respective lines of research by writing articles together, attending conferences and seminars, etc. This dialogue, it should be noted, can last very long over the years. The members of this expanded community know one another (by meeting or reading published articles) and are somehow always aware of the most recent published work due to the urge for scientists to publicize their ideas. One researcher explains this collective aspect or research dynamics:

> *I am involved in a huge production process that ranges from the work we do here to what happens in the major labolatories. So we are part of something. You hardly ever have an idea that is totally original and that you can claim to be only yours, that you can consider to be the 'father' of. It's an extremely rare phenomenon. What we usually do is connect things from areas that are sort of akin and that a lot of people work on. If we're skilled to do something, we work in the area that is related to that. To put it simply: I haven't invented a subject but I can connect it with other things. For example, I can propose a way to check if a given idea is somehow experimental. Or if someone didn't realize what their findings meant because they were testing another model. So, what's that? This work is not only mine. My work, my contribution will be that of connecting some of these things, or realizing that a given model can explain something better than another...(...) So, our work basically means participating in what is done all over the world. But it's hard enough to try and understand what people are doing. It's complicated to understand something and then also contribute to it.*

Aspects of network functioning

To perform their activities, the groups contact other institutions, suppliers of raw materials and equipment, and also other teams in the PI. These relations characterize another phenomenon found in research work: network production. The network phenomenon encompasses the general network of relations among scientists described by Latour (1997) and Callon (1988), which is formed by laboratories, offices, factories, hospitals, politicians' offices; in other words, all the institutions and groups that benefit from research done in cooperation, through information sharing, grants, etc. And what is this big network like? What features does it have?

Lévy (1993) uses the hypertext metaphor for reality spheres where meanings come into play. He described the model as having six principles that can be applied to the concept of network: (1) Metamorphosis principle: it is the constant change that results from building and renegotiating the network; its design and size depends on the interference of the actors involved. The Quantum Optics Group kept a permanent relation with the *École Normale Supérieure*. They were partners in the area of Fundamental Physics and performed several tests together. According to the coordinator of the group, these relations became somewhat less frequent from 1998 onwards because of changes in the lines of research and the setup of the group's laboratory. (2) Heterogeneity principle: the nodes and connections of a network are heterogeneous. Just like images, sounds, words, sensations, models and smells are found in memory, people, artifacts and natural powers come into play in the socio-technical process. The groups investigated at the PI have strong relations with suppliers, customs, workshops, hospitals, schools, government organizations, state and municipal educational institutions, atoms, molecules, protons, photons, laws of Physics – in summary, a wide network that can help them accomplish their projects. (3) Multiplicity principle of scale fitting: The organization is fractal, that is, any node can be comprised of another network, indefinitely, along scales of degrees of precision. In the collaboration at CERN investigated in this study, there are 50 researchers from 15 institutions who, in turn, are each part of another group that is connected with other groups. (4) Exterior Bias Principle: the network does not have either an organic unit or an internal engine; its increase and decrease, its composition and recomposition depend on an indeterminate exterior: addition of new elements, connections with other networks, flows.

Each research group is connected with other groups. This is unpredictable and depends on several things such as common interests, likelihood of receiving grants, similar lines of research, specific demands. (5) Topology principle: as with hypertext, everything in a network works upon proximity; the course of events depends on the paths chosen.

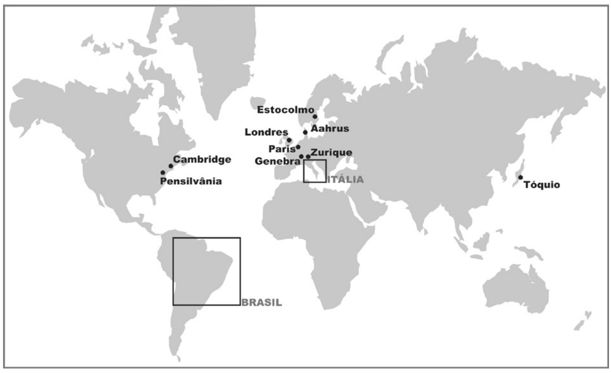
Each research group makes choices that will influence their relations with others. A group can be large and influential at a given moment but smaller at another. This network structure reverberates upon proximity. (6) Center mobility principle: the network does not have a center, just like it has no beginning or end. It has different centers that constantly move from one node to another. There are infinite mobile ramifications around these centers that create different meaning scenarios. In these centers we can identify the funding and the contacts with other centers, institutes and research groups in the states and countries where they take place. Each point has to be conceived as a "node" in the network which, in turn, is connected with other groups and institutions. The first group has connections with a financing agency in Brasília and Rio de Janeiro, with research institutes in Rio de Janeiro and with an international laboratory which supplies crystal samples for analysis. The second group is connected with a financing agency in Brasilia, with universities and research institutes in eigth countries and three Brazilian states besides Rio de Janeiro. The third group is connected with a financing agency in Brasilia and Rio, with centers for the popularization of science, graduate programs and publishers. It hosted several students from different cities in the state of Rio de Janeiro who participated in a refresher course for secondary education teachers.

Discussion: work method is crucial for the type of production

Another focus to the notion of network is used by authors of the Organizational Theory. This theory differs from the theoretical benchmarks above-mentioned but is also relevant to analyze the research groups. It advocates that the concept of network is related to the concept of strategy, that is, something that entrepreneurs use to gain competitive advantage for their companies (see JARILLO, 1998; MILES & SNOW, 1984; D'AMOURS et al.,1995; GRANDORI & SODA, 1995; AMATO NETO, 2001). These studies consider networks as complex arrangements of relations among companies. In this scenario, competition is more closely related to position in a network than attack on an outside environment, as these approaches focus on the systemic view which considers a circumscribed inside element and an outside element beyond such limit. Thus, in order to be competitive in the new environment, business units expand into branches and modify their structures towards more flexible directions, shaping into networks. Such business networks are comprised of "nodes" (economic units) and connections (relations) among the "nodes". They group together specialist companies that can produce a wide range of products in smaller amounts when they are efficiently coordinated. One good example of this logic is the Genoma Project, funded by Fapesp[7], which mapped the genetic structure of bacterium Xyllela fastidiosa, the pathogenic agent for citrus variegated chlorosis (resulting in losses of up to U$ 100 million to orange producers). Its organizational structure is that of a network with competitive goals in the mastery of molecular biology techniques. It was comprised of 35 laboratories and 192 scientists located in different municipalities in the state of São Paulo, each one being in charge of a part of the project.

Also within this logic, as regards networks that are set up to do research, work can be seen to take place in modules, as a non-steady collective, due to an exchange among agents. At the same time, it is about a non-homogeneous collective as it engenders confrontations among different organizational micro-cultures, with representations and conceptions that differ a great deal from the activities of such cultures. Such features cause these collectives to share intentions, negotiate contracts, and articulate with different levels of organization. This study has observed that researchers at the PI begin to build their network of relations while they are still master's and doctoral students and continue to expand it as they pursue their careers. Some researchers at the PI have set up a highly diversified work network, which enables producing articles with several researchers all over the world (Figures 1 and 2).

Figure 1 – Research network of a group investigated at the Physics Institute.



Source: Alvarez, 2004.

An example of this type of organization is the experimental physics group at the Physics Institute, which started in 1993. It has 16 members and works collaboratively. It takes a multidisciplinary approach; its members come from different areas and departments (Mathematics, Computer

Science, Electrical Engineering) and work together with large international groups with more than 500 researchers. This group does research on Elementary Particle Physics, more particularly High-Energy Experimental Physics. It uses the particle accelerator known as *Large Electron-Positron Collider* – LEP, located at CERN, and collaborates with five international projects: three of them at CERN, one in the field of astrophysics; one in the US and one in Argentina. Another example of research network is the ATHENA project, which has as a member one of the researchers from the group of Quantum Optics investigated in this study. This is another collaborative project at CERN and proposes an experiment to produce and investigate antihydrogen in order to check whether the CPT (Charge, Parity and Time) symmetry – a "basic natural symmetry" - remains unaltered. The project is comprised of 17 institutions and 50 researchers. Each one of them is in charge of developing a part of the experiment and contributing with funds. In 2010, each laboratory had their equipment assembled at CERN and they all started to run the experiments that have been receiving wide media coverage.

What information is and how it flows

One relevant feature of research in the field of theoretical physics is the speed of information flow. Those devoted to Theoretical Physics and the so-called 'state-of-the-art' research classify information as crucial input to their work, as emphasized by the coordinator of the Quantum Optics group:

> *Information is about awareness of upcoming preprints, and of articles in the most renowned journals. So, in my area, online subscriptions to Physical Review and to Physical Review Letters are extremely important. You should read this kind of journals, check Los Alamos, check other journals that are available in the library. (...)This is what information is about, to some extent: books, journals, preprints, information from conferences or obtained from other researchers; this is all very important. By the way, conferences are crucial because you get a lot of fresh ideas.*

In all areas of Physics, and mainly in Fundamental Physics, information flow is paramount. Scientific information is spread through both formal and informal channels. Latour (1997) states that informal channels are more prevalent in places where there is a large network of contacts which behave somewhat like invisible brotherhoods. Very often, informal information sharing - for example, over the phone, during lunch time, during a visit to a researcher – is about issues addressed in published books and articles. Undoubtedly, the world of informal sharing is denser and in some ways more disperse than the literature that motivates it.

It is not easy for researchers to keep track of the latest publications because the university has a slow process of purchase through procurement and tendering. A visit to the library brings awareness of the importance of information flow. One third of the library's inventory is comprised of books and theses/dissertations, while the remaining portion is made of journals. Journals have particular features: they focus on very specific areas of knowledge in Physics (Nuclear Physics, Particle Physics, Solid-State Physics, etc.) and differ on publication frequency. There are weekly journals with short articles on the status of the most recent studies; there are monthly journals with short articles and journals that publish longer articles - called reviews - on a given topic. Besides, a preview of what is coming next is made available to online subscribers by editors that release the abstract of articles to be published in the next issue. This way, reseachers can be aware of forthcoming issues one month prior to publication.

Figure 2: Article produced in one collaborative project at CERN. Partial list of authors.

P.Abreu[21], W.Adam[49], T.Adye[36], P.Adzic[11], I.Ajinenko[41], G.D.Alekseev[16], R.Alemany[48], P.P.Allport[22], S.Almehed[24], U.Amaldi[9], S.Amato[46], P.Andersson[43], A.Andreazza[9], P.Antilogus[9], W-D.Apel[17], Y.Arnoud[14], B.Åsman[43], J-E.Augustin[25], A.Augustinus[9], P.Baillon[9], P.Bambade[19], F.Barao[21], M.Barbi[46], G.Barbiellini[45], D.Y.Bardin[16], G.Barker[9], A.Baroncelli[39], O.Barring[24], M.J.Bates[36], M.Battaglia[15], M.Baubillier[23], J.Baudot[38], K-H.Becks[51], M.Begalli[6], P.Beilliere[8], Yu.Belokopytov[9,52], K.Belous[41], A.C.Benvenuti[5], C.Berat[14], M.Berggren[46], D.Bertini[25], D.Bertrand[2], M.Besancon[38], F.Bianchi[44], M.Bigi[44], M.S.Bilenky[16], P.Billoir[23], M-A.Bizouard[19], D.Bloch[10], M.Blume[51], M.Bonesini[27], W.Bonivento[27], M.Boonekamp[38], P.S.L.Booth[22], A.W.Borgland[4], G.Borisov[38,41], C.Bosio[39], O.Botner[47], E.Boudinov[30], B.Bouquet[19], C.Bourdarios[19], T.J.V.Bowcock[22], I.Bozovic[11], M.Bozzo[13], P.Branchini[39], K.D.Brand[35], T.Brenke[51], R.A.Brenner[47], R.C.A.Brown[9], P.Bruckman[35], J-M.Brunet[8], L.Bugge[32], T.Buran[32], T.Burgsmueller[51], P.Buschmann[51], S.Cabrera[48], M.Caccia[27], M.Calvi[27], A.J.Camacho Rozas[40], T.Camporesi[9], V.Canale[37], M.Canepa[13], F.Carena[9], L.Carroll[22], C.Caso[13], M.V.Castillo Gimenez[48], A.Cattai[9], F.R.Cavallo[5], V.Chabaud[9], Ph.Charpentier[9], L.Chaussard[25], P.Checchia[35], G.A.Chelkov[16], M.Chen[2], R.Chierici[44], P.Chliapnikov[41], P.Chochula[7], V.Chorowicz[25], J.Chudoba[29], V.Cindro[42], P.Collins[9], M.Colomer[48], R.Contri[13], E.Cortina[48], G.Cosme[19], F.Cossutti[45], J-H.Cowell[22], H.B.Crawley[1], D.Crennell[36], G.Crosetti[13], J.Cuevas Maestro[33], S.Czellar[15], J.Dahm[51], B.Dalmagne[19], G.Damgaard[28], P.D.Dauncey[36], M.Davenport[9], W.Da Silva[23], A.Deghorain[2], G.Della Ricca[45], P.Delpierre[26], N.Demaria[34], A.De Angelis[9], W.De Boer[17], S.De Brabandere[2], C.De Clercq[2], C.De La Vaissiere[23], B.De Lotto[45], A.De Min[35], L.De Paula[46], H.Dijkstra[9], L.Di Ciaccio[37], A.Di Diodato[37], A.Djannati[8], J.Dolbeau[8], K.Doroba[50], M.Dracos[10], J.Drees[51], K.-A.Drees[51], M.Dris[31], J-D.Durand[25,9], D.Edsall[1], R.Ehret[17], G.Eigen[4], T.Ekelof[47], G.Ekspong[43], M.Ellert[47], M.Elsing[9], J-P.Engel[10], B.Erzen[42], M.Espirito Santo[21], E.Falk[24], G.Fanourakis[11], D.Fassouliotis[45], J.Fayot[23], M.Feindt[17], P.Ferrari[27], A.Ferrer[48], S.Fichet[23], A.Firestone[1], P.-A.Fischer[9], H.Foeth[9], E.Fokitis[31], F.Fontanelli[13], F.Formenti[9], B.Franek[36], A.G.Frodesen[4], R.Fruhwirth[49], F.Fulda-Quenzer[19], J.Fuster[48], A.Galloni[22], D.Gamba[44], M.Gandelman[46], C.Garcia[48], J.Garcia[40], C.Gaspar[9], U.Gasparini[35], Ph.Gavillet[9], E.N.Gazis[31], D.Gele[10], J-P.Gerber[10], L.Gerdyukov[41], R.Gokieli[50], B.Golob[42], P.Goncalves[21], G.Gopal[36], L.Gorn[1], M.Gorski[50], Yu.Gouz[44,52], V.Gracco[13], E.Graziani[39], C.Green[22], A.Grefrath[51], P.Gris[38], G.Grosdidier[19], K.Grzelak[50], M.Gunther[47], J.Guy[36], F.Hahn[9], S.Hahn[51], S.Haider[9], Z.Hajduk[18], A.Hallgren[47], K.Hamacher[51], F.J.Harris[34], V.Hedberg[24], S.Heising[17], R.Henriques[21], J.J.Hernandez[48], P.Herquet[2], H.Herr[9], T.L.Hessing[34], J.-M.Heuser[51], E.Higon[48], S-O.Holmgren[43], P.J.Holt[34], D.Holthuizen[30], S.Hoorelbeke[2], M.Houlden[22], J.Hrubec[49], K.Huet[2], K.Hultqvist[43], J.N.Jackson[22], R.Jacobsson[43], P.Jalocha[9], R.Janik[7], Ch.Jarlskog[24], G.Jarlskog[24], P.Jarry[38], B.Jean-Marie[19], E.K.Johansson[43], L.Jonsson[24], P.Jonsson[24], C.Joram[9], P.Juillot[10], M.Kaiser[17], F.Kapusta[23], K.Karafasoulis[11], S.Katsanevas[25], E.C.Katsoufis[31], R.Keranen[4], Yu.Khokhlov[41], B.A.Khomenko[16], N.N.Khovanski[16], B.King[22], N.J.Kjaer[30], O.Klapp[51], H.Klein[9], P.Kluit[30], D.Knoblauch[17], P.Kokkinias[11], M.Koratzinos[9], K.Korcyl[18], V.Kostioukhine[41], C.Kourkoumelis[3], O.Kouznetsov[16], M.Krammer[49], C.Kreuter[9], I.Kronkvist[24], J.Krstic[11], Z.Krumstein[16], P.Kubinec[7], W.Kucewicz[18], K.Kurvinen[15], C.Lacasta[9], I.Laktineh[25], J.W.Lamsa[1], L.Lanceri[45], D.W.Lane[1], P.Langefeld[51], J-P.Laugier[38], R.Lauhakangas[15], G.Leder[49], F.Ledroit[14], V.Lefebure[2], C.K.Legan[1], A.Leisos[11], R.Leitner[29], J.Lemonne[2], G.Lenzen[51], V.Lepeltier[19], T.Lesiak[18], M.Lethuillier[38], J.Libby[34], D.Liko[9], A.Lipniacka[43], I.Lippi[35], B.Loerstad[24], J.G.Loken[34], J.M.Lopez[40], D.Loukas[11], P.Lutz[38], L.Lyons[34], J.MacNaughton[49], J.R.Mahon[6], A.Maio[21], T.G.M.Malmgren[43], V.Malychev[16], F.Mandl[49], J.Marco[40], R.Marco[40], B.Marechal[46], M.Margoni[35], J-C.Marin[9], C.Mariotti[9], A.Markou[11], C.Martinez-Rivero[33], F.Martinez-Vidal[48], S.Marti i Garcia[22], F.Matorras[40], C.Matteuzzi[27], G.Matthiae[37], M.Mazzucato[35], M.Mc Cubbin[22], R.Mc Kay[1], R.Mc Nulty[9], G.Mc Pherson[22], J.Medbo[47], C.Meroni[27], W.T.Meyer[1], A.Miagkov[41], M.Michelotto[35], E.Migliore[44], L.Mirabito[25], W.A.Mitaroff[49], U.Mjoernmark[24], T.Moa[43], R.Moeller[28], K.Moenig[9], M.R.Monge[13], X.Moreau[23], P.Morettini[13], K.Muenich[51], M.Mulders[30], L.M.Mundim[6], W.J.Murray[36], B.Muryn[14,18], G.Myatt[34], T.Myklebust[32], F.Naraghi[14], F.L.Navarria[5], S.Navas[48], K.Nawrocki[50], P.Negri[27], S.Nemecek[12], N.Neufeld[9], W.Neumann[51], N.Neumeister[49], R.Nicolaidou[14], B.S.Nielsen[28], M.Nieuwenhuizen[30], V.Nikolaenko[10], M.Nikolenko[10,16], P.Niss[43], A.Nomerotski[35], A.Normand[22], A.Nygren[24], W.Oberschulte-Beckmann[17], V.Obraztsov[41], A.G.Olshevski[16], R.Orava[15], G.Orazi[10], S.Ortuno[48], K.Osterberg[15], A.Ouraou[38], P.Paganini[19], M.Paganoni[9,27], S.Paiano[5], R.Pain[23], H.Palka[18], Th.D.Papadopoulou[31], K.Papageorgiou[11], L.Pape[9], C.Parkes[34], F.Parodi[13], U.Parzefall[22], A.Passeri[39], M.Pegoraro[35], L.Peralta[21], H.Pernegger[49], M.Pernicka[49], A.Perrotta[5], C.Petridou[45], A.Petrolini[13], H.T.Phillips[36], G.Piana[13], F.Pierre[38], M.Pimenta[21], E.Piotto[35], T.Podobnik[34], O.Podobrin[9], M.E.Pol[6], G.Polok[18], P.Poropat[45], V.Pozdniakov[16], P.Privitera[37], N.Pukhaeva[16], A.Pullia[27], D.Radojicic[34], S.Ragazzi[27], H.Rahmani[31], J.Rames[12], P.N.Ratoff[20], A.L.Read[32], M.Reale[51], P.Rebecchi[9], N.G.Redaelli[27], M.Regler[49], D.Reid[9], R.Reinhardt[51], P.B.Renton[34], L.K.Resvanis[3], F.Richard[19], J.Ridky[12], G.Rinaudo[44], O.Rohne[32], A.Romero[44], P.Ronchese[35], E.I.Rosenberg[1], P.Rosinsky[7], P.Roudeau[19], T.Rovelli[5], V.Ruhlmann-Kleider[38], A.Ruiz[40], H.Saarikko[15], Y.Sacquin[38], A.Sadovsky[16], G.Sajot[14], J.Salt[48], D.Sampsonidis[11], M.Sannino[13], H.Schneider[17], U.Schwickerath[17], M.A.E.Schyns[51], G.Sciolla[44], F.Scuri[45], P.Seager[20], Y.Sedykh[16], A.M.Segar[34], A.Seitz[17], R.Sekulin[36], R.C.Shellard[6], A.Sheridan[22], P.Siegrist[9,38], R.Silvestre[38], F.Simonetto[35], A.N.Sisakian[16], T.B.Skaali[32], G.Smadja[25], N.Smirnov[41], O.Smirnova[24], G.R.Smith[36], A.Sokolov[41], O.Solovianov[41], R.Sosnowski[50], D.Souza-Santos[6], T.Spassov[21], E.Spiriti[39], P.Sponholz[51], S.Squarcia[13], D.Stampfer[9], C.Stanescu[39], S.Stanic[42], S.Stapnes[32], I.Stavitski[35], K.Stevenson[34], A.Stocchi[19], J.Strauss[49], R.Strub[10], B.Stugu[4], M.Szczekowski[50], M.Szeptycka[50], T.Tabarelli[27], F.Tegenfeldt[47], F.Terranova[27],

Source: Alvarez, 2004.

Concluding remarks

By analyzing the activities of researchers/professors at a physics institute developing basic science projects, we could observe that communication taking place in their daily work environment has unique features which are closely related to work organization. Some of the features found in the groups investigated are the following: network organization; speed of information collection and distribution; information density; multiplicity of codes in use; transversality between different types of organizational functioning (that of the university and that of funding agencies); transversality between distinct hierarchies (graduate students and researchers with different background and experience); transversality across different temporality modes and different collectives. Accounts produced in this context form assets that are constantly recreated and foster a unique setting where a wide range of normative debate takes place. Communication in the work of professors/researchers is shaped by the dialogues occurring in this setting: the *uses of oneself by oneself and by others.* One conclusion of this study is that the specificity of such communication has to be respected, while it poses a difficult challenge – that of making dialogue possible between the ergological process and the instances observed by this study, for example. Such an exercise can shed light on something occurring at the level of activity.

Notes

1. Founded in 1954, CERN (*Laboratoire Européen pour la Physique des Particules*) is a collaborative European company comprised of 19 member States. It is located on both sides of the border between France and Switzerland. Approximately 6,500 scientists from 500 universities in 80 different countries cooperate through CERN and use its facilities. Its mission is to supply physicists with beams of high-energy particles produced in its accelerators.

2. Collaboration is a joint work contract between institutions and researchers where each member is in charge of a part of the project and the results are shared among its members. This type of organization has existed for approximately 20 years in the field of Elementary Particle Physics.

3. The word *constraint* is used here as a translation for the term contrainte, found in the Ergonomics literature. It can be understood as anything in a situation that causes restrictions, difficulty or obstacles.

4. When the field research was conducted in 1998, there were 7,271 research groups in Brazil which accounted for 26, 770 researchers at work. The groups are comprised by doctors mostly, which accounted for 51% of all the researchers all over Brazil.

5. Experimental Physics is devoted to investigating physical phenomena by using experimental processes. It aims to measure relevant physical quantities, or to observe certain physical processes. In Theoretical Physics, theories are expressed and formulated in a mathematical form, where the results obtained experimentally are used to validate general or specific relations therein.

6. CERN is represented by a research and collaboration coordinator and a spokesman who also coordinates research work (elected every 2 years), a contact person, a technical coordinator and a representative of GLIMOS (*Group of Leader in Matters of Safety*), which belongs to CERN. Moreover, each institution has a representative in the project who participates in the group meetings that take place in Geneva. The rights over discoveries that may be patented have to be discussed through collaboration.

7. The Genoma Project started on May 1st 1997 and aimed to produce advancements in the area of biotechnology, foster mastery in molecular biology techniques and transfer such knowledge to other locations. They searched for the DNA sequence of a previously selected bacterium. (Talk entitled "Grants from Fapesp", given by Luiz Perez, Scientific Director at Fapesp, which took place at the Physics Institute of the Federal University of Rio de Janeiro, on October 16th, 1998).

Bibliographic references

ALVAREZ, D. **Cimento não é concreto, tamborim não é pandeiro, pensamento não é dinheiro! Para onde vai a produção acadêmica?** Rio de Janeiro: Myrrha, 2004.

AMATO NETO, J. **Redes de cooperação produtiva e clusters regionais:** oportunidades para as pequenas e médias empresas, São Paulo: Atlas, 2001.

BARTHE, B.; QUÉINNEC, Y. Terminologie et perspectives d'analyse du travail collectif en Ergonomie. **L'Année psychologique,** n.99, p.663-686, 1999.

BREHMER, B. Distributed decision making: some notes on the literature. In: RASMUSSEN, J.; BREHMER, B.; LEPLAT, J. (Eds.). **Distributed decision making:** cognitive models for cooperative work. Chischester: J. Wiley, 1991.

CALLON, M. **The strategic management of research and technology:**evolution of programmes**.** Paris: Economica International, 1997.

CALLON, M. **La science et ses réseaux:** genèse et circulation des faits scientifiques, Paris: Éditions La Découverte, 1988.

CANGUILHEM, G. O objeto da história das ciências: epistemologia. **Revista Tempo Brasileiro,** Rio de Janeiro, n.28, p.7-21, 1972.

COURTEIX-KHEROUF, S. .**Évolution technico-organisationnelle et activités collectives:** la celulle de travail. cas de maintenance operationélle de systèmes du trafic aérien**.** Thèse (Doctorat) – Université de Toulouse II, Toulouse, 1995.

D'AMOURS, S. et al. Advances on networked manufaturing. In: **ENEGEP 95,** 15., 1995, São Carlos. **Anais**... São Carlos,SP: UFSCar, 1995. p.1631-1635.

DANIELLOU, F. **A ergonomia em busca de seus princípios:** debates epistemológicos, São Paulo: Edgard Blücher, 2004.

DEJOURS, C. **A loucura do trabalho:** estudo de psicopatologia do trabalho. São Paulo: Cortez-Oboré, 1991.

DEJOURS, C. De la psychopatologie à la psychodynamique du travail. In: DEJOURS, C. **Travail, usure mentale,** Paris: Bayard, 1993. p.205-259.

DIRETÓRIO dos Grupos de Pesquisa 1995. Disponível em: <http://www.cnpq.br/dgp.html>. Acesso em: 1 mar. 1998.

ESTUDO paulista decifra genoma de praga agrícola, **Folha de São Paulo,** São Paulo, p.34, 18 fev. 2000.

GUERIN, F. **Compreender o trabalho para transformá-lo,** São Paulo: Edgard Blücher, 2001.

GRANDORI, A.; SODA, G. Inter-firm networks: antecedents, mechanisms and forms. **Organisation Studies,** v.16, n.2, p.183-214, 1995.

JARILLO, J.C. On strategic networks. **Strategic Manegement Journal,** p.31-41, dec., 1988.

LATOUR, B. Faut-il parler de l'histoire des faits? Le chercheur doit chioisir: résumer les faits ou dresser la carte des controverses. **La Recherche,** n.291, p.84, oct., 1996.

LATOUR, B.; WOOLGAR, S. **A vida em laboratório:** a produção dos fatos científicos, Rio de Janeiro: Relume Dumará, 1997.

LÉVY, P. **As tecnologias da inteligência:** o futuro do pensamento na era da informática. Rio de Janeiro: Editora 34, 1993.

MARTINS, G.M.; GALVÃO, G. O Diretório dos Grupos de Pesquisa no Brasil: perspectivas de fomento e avaliação. **Educação Brasileira,** Brasília, v.16, n.33, p.11-29, 1994.

MILES, R.E.; SNOW, C.C. Fite Failure and the hall of fame. **California Manegement Review,** v.26, n.3, p.10-28, 1984.

NAVARRO, C. Une analyse cognitive de l'interaction dans les activités de travail. **Le Travail Humain,** v.54, n.2, p.113-128, 1991.

RIP, A.; GROENEWEGEN, P. Les faits scientifiques à l'épreuve de la politique. In : CALLON, M. (Org.). **La science et ses réseaux :** genèse et circulation de faits scientifiques, Paris: La Découverte, 1988. p.149-172.

SEMINÁRIO SOBRE FINANCIAMENTO À PESQUISA DA FAPESP. 1996, Rio de Janeiro. Luiz Perez, Diretor Científico da FAPESP. Rio de Janeiro: Instituto de Física. UFRJ, 1996.

SCHMIDT, K. Cooperative work: a conceptual framework. In: RASMUSSEN, J.; BREHMER, B.; LEPLAT, J. (Eds.). **Distributed decision making:** cognitive models for cooperative work. Chischester: J. Wiley, 1991. p.75-111.

SCHWARTZ, Y. **Le paradigme ergologique ou un métier de philosophe,** Toulouse: Octarès, 2000.

SCHWARTZ, Y. **DISCIPLINE ÉPISTEMIQUE, DICIPLINE ERGOLOGIQUE:** PAIDEA ET POLITEIA, MANIÈRES DE PENSER, MANIÈRES D'AGIR EN EDUCATION ET EN FORMATION, Paris: PUF, 2000A.

SCHWARTZ, Y.; DURRIVE, L. (ORGS.). **TRABALHO E ERGOLOGIA:** CONVERSAS SOBRE A ATIVIDADE HUMANA. NITERÓI: Eduff, 2007.

TEIGER, C.; LAVILLE, A. **L'expression des travailleurs sur leurs conditions de travail.** Rapport n.100. Paris: CNAM, 1989. 2v. Collection du Laboratoire d'Ergonomie et de Neurophysiologie du Travail.

VIDAL, M.C. Sobre o trabalho de pesquisa em equipe integrada de pesquisa: construindo uma orientação em rede. ENEGEP 95, 15., 1995, São Carlos; INTERNATIONAL CONGRESS OF INDUSTRIAL ENGINEERING, 1., 1995, São Carlos; NATIONAL CONGRESS OF PRODUCTION ENGINEERING, 15., 1995, São Carlos. **Anais...** São Carlos: Abepro/UFSCar, 1995.

WISNER, A. **A inteligência no trabalho,** São Paulo: Fundacentro, [1981] 1994.