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10. Miettinen, R. (2006). Pragmatism and activity theory: Is Dewey's philosophy a philosophy of cultural retooling? *Outlines, Critical Social Studies*, 8 (2), 3–19.

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# INTRODUCTION: THE ROOTS OF THE DIALOGUE

Georg Rückriem generously suggested to me in 2006 that a collection of my papers could be published as a volume in the series of International Cultural-Historical Human Sciences series. The chapters included in this book that emerged from this initiative have two origins related to my professional career. In the 1980s I worked as a planning officer at the Technical Research Center Finland in charge of the training of the research scientists. Much of the training was about how to organize the research work and how to effect the utilization research results. In order to find resources to meet these challenges, I started to become acquainted with the results emerging from science and technology studies, a multidisciplinary research area that had started in the late 1970s to study how scientific facts are constructed in laboratories. In the 1980s the idea of ‘social construction’ was extended to the study of technical artifacts and innovations (Pinch & Bijker 1987, Latour 1987).

On the other hand, starting in the late 1970s I participated in an unofficial group of scholars and practitioners who was reforming the ways in which learning and the development of work can be achieved in organizations. This work lead to the establishment of an approach that became known as Developmental Work Research. Its theoretical foundations were formulated by Yrjö Engeström in 1987 in his book *Learning by Expanding*. The Center for Activity Theory and Developmental Work Research was founded in 1995 in the Department of Education of the University of Helsinki. I moved there and formed a research group that started to study the research work and innovation processes from the perspective of activity theory.

I was privileged to work with a group of talented doctoral students who came from history, philosophy, sociology and adult education. Each had her or his own research site and research problems. Eveliina Saari (2003) studied the developmental dynamics and division of labour of an aerosol research group, and Juha Tuunainen (2004) did the same for a plant biotechnology research group that established a biotechnology firm trying to function as ‘a hybrid’ within the University of Helsinki. Mervi Hasu (2001) studied the producer-user relationship in the development of a brain imaging system based on cold physics, and Janne Lehankari (2006) studied networks of learning in the development of a functional food product, Benecol margarine, and a diabetes software. Sampsa Hyysalo (2004) analysed the design of a care wrist device and the ways that the designer firm tried to make sense of user needs and to learn through pilot users.

Tarja Knuuttila (2005) studied models in scientific work by analysing the development of a parser in a language technology research group, and Erika Mattila (2006) studied the collaboration of statisticians, epidemiologists and information scientists in the construction of a family of models of the transmission of infectious diseases. It is interesting that even in the philosophy of modeling, activity became a key issue in the 1990s. Models were increasingly seen as mediating instruments rather than only representations of world (Morgan & Morrison 1999). To understand the nature of models and modeling, the study of both the construction and uses of models in scientific work and in societal practices is needed. This was the challenge to which Tarja and Erika met in their dissertations.

This collection of papers is greatly inspired by this unforgettable group collaboration in which studying the foundations of science and technology studies played a central role. The book does not do justice to the richness of the research results of the group members published in the papers and in the dissertations listed above. Fortunately, they are mainly published in English and available to readers.[1] Eveliina Saari and Mervi Hasu kindly allowed me to include to this collection papers that were based on their fieldwork and written together with me (chapters 2 and 3). So did two old dear colleagues of mine, Seppo Peisa (ch 11) and Jaakko Virkkunen (ch 15). As a result the papers cover quite a rich array of activities and technologies. This short personal history explains the starting point for the essays of this book: a dialogue between cultural-historical activity theory and the approaches developed by science and technology studies in order to understand and to study the dynamics of research work and research-based innovations.

The term ‘dialogue’ is in the title of the book because almost in every paper activity theory is compared with other theoretical approaches, such as Deweyan pragmatism, actor network theory, the systems view in history of technology, the systemic view in psychology of creativity, neo-institutional organization theory and theory of recognition, which originated from Hegel and was developed further by philosophical anthropologists. This comparison is done for three reasons. Firstly, these approaches do supply complementary resources and points of view for making sense of the different aspects of scientific work and innovations. Secondly, I think that any theoretical approach – with its strengths ands possible weaknesses – becomes articulated when it is compared with other approaches. Consequently, I hope this book contributes to the articulation of the potentialities

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[1] To find their scientific papers, please check the list of references of the book.

and possible uses of activity theory. Thirdly, the comparisons were also made to introduce activity theory to researchers in fields where it is not widely known, such as science and technology, innovation and organization studies.

The term ‘creativity’ is included in the title with ‘dialogue’ in a natural way. The cases analysed in the book show one after another that the creation of something new (facts, technologies, and practices) emerges from encounters between activities with different resources and understandings. Therefore, an attempt to find the complementary resources and pursue a dialogue between activity theory, science and technology studies, pragmatism and the systemic psychology of creativity in studying scientific and technological activities corresponds to what was found in the innovations and activities studied in the chapters of this book.

I am fully aware of the challenge of using the term ‘dialogue’. As Gadamer (2005, 214) suggests, the presentation of arguments and counterarguments should develop the possibility of “being otherwise”, knowing yourself through the recognition of others. Although the essays often critically evaluate other theoretical traditions and authors from the point of view of activity theory, I hope they do justice to these traditions and authors and clarify something in both them and in activity theory.

The book is organized into three parts. The first part (chapters 1–6) is composed of texts that emerged from empirical studies of research work and innovations in analytical chemistry, aerosol and enzyme research as well as in the development of health technologies. Three problems are dealt with in them: firstly, how the object of an activity or the local research programme of a research group evolves; secondly, the problem of invention, that is, how ideas of new products and services emerge; and thirdly, how these inventions turn into innovations, that is, become implemented in practice and introduced into the market. The studies show that the motives of gaining scientific understanding and of using the knowledge and expertise to solve practical problems were deeply intertwined in the work of research groups. Correspondingly, they collaborate both with other research groups and with users and clients: the activity and innovations evolved in what was characterized by science studies as transepistemic arenas of collaboration (Knorr-Cetina 1992) and by innovation studies as networks of innovation (Freeman 1991) and networks of learning (Powell et al. 1996). The problems, challenges and mechanisms of these collaborative relationships are illuminated in the five first chapters of this book.

A central mediating mechanism in collaboration turned out to be the production of experimental effects in the laboratory: they are used as effects in technological systems and made into ‘epistemic objects’ to be explained by using the resources of science (Miettinen 1999). Often experiments are predicated by practical needs, and their results are used and applied first and explained only later. This underlines the significance of collaboration with users as a central means of inducing innovations both in science and technology.

The first paper analyses the development and use of the Neutron Activation Analysis (NAA) method in a research laboratory to determine the composition of elements in biological, geological and environmental samples for various purposes, from the study of the pollution of lakes and rivers in Finland to gold detection. The contradictory nature of the NAA work becomes visible: economic pressures drive the work towards mass analytic services, which is realized by automatization of the analysis system. The researchers found that this deteriorated the possibilities to use and develop the method for studying socially important and scientifically interesting problems. The automatization – very much comparable to industrial automation – deeply influenced the contents of the work and the division of labour between the researchers and research assistants.

Chapter 2 studies how a local research programme of an aerosol research group developed. The collaboration with other research groups and with users and clients proved to play a decisive role in the process. The emergence of a new research area, the production of aerosol particles by a pyrolysis reactor, emerged from a joint project with an American research group. The collaboration with clients decisively influenced the direction of the research and the capabilities of the research group. The problems of producing particles required theoretical understanding of what happened in the reactor.

Chapter 3 deals with how user needs can be analysed and utilized in an innovation process. The paper studies the development of a high-technology product, a system used to analyse the magnetic activity of the human cortex, by a small spin-off firm called Neuromag. At the time the study started, the firm was working towards of  having the system introduced into clinical use. It, however, turned out that the firm had never met the potential future users. To this end, the researchers organized a user seminar, in which surgeons and imaging specialists from two hospitals articulated their views of the conditions of implementing the imaging method in hospital work. Several previously unrecognized problems came up and lead to developmental measures by Neuromag (see Hasu & Miettinen 2006). The study shows the limitations of technology-driven innovations and the increased need for collaboration between producers and users, nowadays often characterized in terms of co-configuration (Victor & Bouynton 1998) and the democratization of innovation (V. Hippel 2005).

Chapter 4 evaluates how four prevailing theories of invention manage to make sense of an innovation: the development of an enzyme-ended pulp bleaching process by a biotechnology laboratory. The four theories are 1) a psychological *genius theory* of invention that regards the inventiveness of a talented individual as a starting point, 2) the *theory of cultural preparation* suggested by Robert Merton, 3) the sociological *theory of attribution* and 4) the *theory of serenpidity*. The analysis of the innovation process shows that the genius theory could not explain the case at all: it was a collective distributed invention from the beginning. Each of the other three theories, however, helped to make sense of important aspects of the innovation process.

Chapter 5 studies the relationship between a key individual's contribution and the contribution made by a network collaboration in the development of a new kind of immunodiagnostic test. It shows how the idea of a new alternative test emerged from a long-standing collaboration between the firm and the key user. The critical problem of the prevailing immunodiagnostic practice that needed to be solved was learned from the users. The knowledge and resources of many actors were used in the development of the new method and in solving the problems related to it. The persistence of the 'innovator', the research director of Wallac, was combined with extensive collaboration with other research groups, firms and hospitals to find the insight and expertise needed in the development of the new method.

Chapter 6 summarizes and looks for converging foundations for understanding distributed and social creativity from cultural psychology, organizational and innovation studies as well as from history of science and technology. The history and possibility of the 'management' of creativity are discussed. Since contingency is an essential part of creativity, the planning in a traditional sense is hardly possible. Instead, the study and understanding of the 'critical problems' and contradictions of technology use, the new emerging forms of practices as well as horizontal collaboration across traditional domains of expertise supply foundations for recognizing important problems and new possibilities that call for creative solutions.

The second part of this book (chapters 7–11) compares activity theory and pragmatism as theories of human activity, thought and learning. It is argued that both of these theories supply in many senses a more viable conception of the nature of humans than most of the 'social practice' theories that became fashionable in early 2000s (Reckwitz 2002). Several philosophers and social scientists have found similarities in Dewey's and Marx's concepts of practice. Bertrand Russel (1951) thought that this commonality might be found in their shared roots in Hegel. The five papers of the chapter discuss the similarities and differences between activity theory and Dewyan pragmatism as well as their significance for the study of change and the development of human activities.

The first paper (chapter 7) introduces Dewey's theory of reflective thought and action in the form of the critique of David Kolb's theory of experiential learning. This theory has an enduring influence in organizational studies. It is shown that, contrary to the author's claim, its concept of experience is radically different from that of Dewey's concept, which regards material interaction with the environment as fundamental and sees experimentation based on a working hypothesis as a basic way of knowing.

Chapter 8 analyses the most important similarities between activity theory and Deweyan pragmatism. Both regard practice and activity as key theoretical concepts in resolving the Cartesian dualism between subject and object. Both regard practical material interaction with the world or 'life activity' to be ontologically and epistemologically primary in relation to thought and cognition. They find work, or the transformation of reality, as a basic model of such interaction. Both see reality as something constantly changing, which presumes constant reorientation and retooling in human activities. Therefore, they also find experimentation and intervention to be essential in studying society and human practices.

Chapter 9 is a critical comment on a paper published by Jim Garrison (2005) in *Mind, Culture and Activity*. He found that activity theory remains captured by dualism and presentative realism because it draws a distinction between the internal and external. He suggests that Dewey's transactionist concept of activity is a genuine nondualist solution and constitutes an alternative to activity theory. The chapter suggests against this position that there are no decisive ontological differences between activity theory's concept of mediated activity and Dewey's transactional concept of activity. However, even if the subject and object co-evolve and are located in the same ontological sphere, the division of this ontological unity into the dialectics of subject and object is a sensible methodological solution for the study of human activity.

Chapter 10 discusses the consequences of Dewey's use of Darwin-inspired biological language in the formulation of his theory of inquiry and reflective thought. His concepts of 'habit' and 'situation' are central in this formulation. It is argued that this language is somewhat insensitive to historicity and cultural artifacts. Although the theory implies the reconstruction of the environment, retooling and developing the new instrumentalities do not have a well-articulated methodological role in Dewey's idea of the processes of problem solving and reflective thinking.

Chapter 11 reports the results study of a teaching experiment in a Finnish polytechnics in which a group of students studied the main problems found in a partner firm and suggested solutions to them. This paper used complementary resources both from Dewey and from activity theory in framing and substantiating the teaching experiment. Both of these theories look for the solution to the problem of the traditional school learning in reintegrating the learning of new knowledge into the context of use.

The third part of the book (chapters 12–16) supplies five comparative theoretical papers. Activity theory and actor network theory are compared as frameworks for studying innovation, the uses of the 'constructivist conception of learning' are evaluated and well as the limitations of the concept of 'routine' – largely used in organizational studies – in attempts to understand organizational change. Two of the papers deal with the concept of 'object of activity' central to the activity theoretical research inspired by Leont'ev. It is argued that the motives of individuals are anchored to the artifact-related capabilities with which an individual contributes to the construction of an object of activity. These developing capabilities are transferable to other activities with different objects. The final chapter compares how three interventionist approaches in social sciences understand what is essential in developmental intervention.

Chapter 12 compares activity theory and actor network theory as approaches to studying innovations. Actor network theory is perhaps the most influential of the theories that emerged within the constructivist science and technology studies in the 1980s and 1990s. When I started to study technical innovations in the late 1980s, I found its idea of studying innovations as the co-evolution of the object and network actors related to it as a promising methodological idea analogous to of the activity theoretical concept of object construction (Miettinen 1993). The differences between activity theory's dialectical and actor network theory's symmetrical concepts of mediation are discussed. It is argued that the attempt of actor network theorists to create an approach that treats humans and non-humans symmetrically – based on the concept of power – in reality results in the exclusion of the contribution of both the key human actors (designers, engineers, workers, users) and the material artifacts from the analysis.

Chapter 13 discusses the concept of constructivism in education and the classifications of the versions of constructivism in education. It makes distinctions between neo-Kantian, social and heterogeneous constructionism. It concludes that the concept of constructivism in education – like its counterpart in sociology and science and technology studies (e.g. Hacking 1999) – has extended to cover so many phenomena and theoretical approaches that it is no longer able to highlight important differences between theories.

Chapter 14 discusses the relationships between individual motives and objects of collective activities. Since objects of collective activities are complex systems, they call for combining very different kinds of knowledge, resources and instrumentalities. Individuals contribute to the construction of such objects with specific artifact-related capabilities that are transferable to other activities. The originally Hegelian theory of the need for recognition suggests that these object-related capabilities also constitute a basis for professional identity: individuals look for recognition in professional, scientific and work communities through their objectified contributions. It is suggested that Howard Gruber's (1981) concept of the individual as "a unique host of a living network of enterprises" could be used to elaborate further Leont'ev's idea of the motivational lines of an individual and how these lines are connected to the life history of an individual and her participation to the different activities and cultural domains.

Chapter 15 compares the concepts of neo-institutional organizational theory and the activity theory of organizational change. It argues that the concepts of capability and routine largely used in organizational theory make it difficult to understand the dynamics of change. The term 'epistemic object' by Knorr-Cetina (1997) is used to argue that an activity and its contradictions must be made into an object of reflection to enhance change. Specific conceptual artifacts – such as the model of an activity system – are needed for this task. An example of a project inspired by development work research is presented. In it a Finnish labour protection organization recognized the central contradictions of its activity and developed a new system of instrumentalities and a new division of labour in order to solve these contradictions.

The final chapter, chapter 16 is based on a presentation given in the seminar *Development intervention – Methodological approaches and debates* held in Helsinki (Kontinen 2004). It discusses the problems of objectivity and 'taking sides' in social research and the relationship of the values of being critical (of power relationships) and of the commitment to make the life of people better. It compares three interventionist approaches developed in three different contexts.

Whereas Norman Long and Bengt Flyberg find that intervention creates ‘arenas of struggle and contestation’ where researchers may function as bridge builders, developmental work research underlines more the possibilities of retooling and collective learning. The researcher can contribute to intervention by bringing new mediational means – concepts and research data – to the intervention to enhance development.

The papers are reprinted with few changes. The references have been updated and some terminological changes have been made. For instance, in several instances the concept of agent has been used with or instead of subject, especially in the cases where several people within an activity system were committed to the transformation of an object of activity. In chapters 13 and 14 I have done some rewriting, making clarifications and additions to render their message clearer. The essays in the book were originally published in nine different journals. I want to thank their publishers for giving permission for their inclusion in this collection.

Helsinki May 18th 2009
Reijo Miettinen

# 1 LABORATORY WORK IN CHANGING SOCIETY: NEUTRON ACTIVATION ANALYSIS IN A RESEARCH LABORATORY[2]

## Introduction

The original motive of this study was to gain understanding of the division of labour in laboratory work and the contents of the work of the laboratory assistants. The motive expanded to an attempt to analyze the development of work in the analytic section of the Reactor Laboratory of the Technical Research Centre of Finland. During the 25 years of its activity the dominant method used has been neutron activation analysis (NAA). Accordingly the major work done in the analytic section can be called neutron activation analysis work (NAA-work).

Some pioneering laboratory studies have been done within the tradition of the constructivist sociology of knowledge. This tradition has a definite epistemological program. It attempts to explain the development and nature of knowledge by studying empirically how it is produced in concrete laboratory settings (Latour & Woolgar 1979, Knorr-Cetina 1981). To omit the old objectivist and idealizing concepts of science, the laboratory should be studied as a “tribe”, with an ethnographic approach.

From the point of view of the present study this approach has at least three limitations. Firstly, because of its epistemological commitments it focuses on certain aspects of laboratory life, first of all on the discussions, interpretations and decisions of the scientists. The labs seem to be manned by scientists only. The contribution of the laboratory assistants is largely omitted. Secondly, the constructivist interpretation of the social determination of laboratory work and its results seems too arrow. Its radical emphasis on the particularity and occasioned nature of laboratory work seems to omit important societal aspects of objects, the instruments and the division of labor of research work. Thirdly, to retain objectivity the researchers studied are not allowed to reflect and interpret their own work processes. In this study this principle has not been followed, because the researchers and research assistants evidently were capable of reflecting important

[2] Published (1990) in *Science Studies*, 3 (2), 35–52.

aspects of their work. These reflections are used in the reconstruction of the development of NAA-work.

This study is not primarily an attempt to contribute to sociology of knowledge. It represents rather, a tradition of psychological and sociological studies of work. Its general frame of reference is the cultural-historical theory of activity. This depicts human activity as object oriented, material activity mediated by cultural artefacts, signs and tools (Vygotsky 1979). During the last years this approach has been used in research on the development of work and qualifications. Work is understood as an *activity system* with a division of labour and rules (Engeström 1987). There is an interdependence between the main elements of the work (subject, tools, object and division of labor and rules). Contradictions and tensions within the system and between the elements of the system are a central "moving force" of development. This approach has been developed in studies on automated industrial work (Toikka & al. 1990), general practitioners' work in health centres (Engeström 1990) and in the work of teaching (Miettinen 1989). Scientific work, as well, can be analyzed as such an activity system (Ruben 1979, Miettinen 1988). As societal work science, of course, has a historically specific nature that concerns both its object, results and means.

Human activity is always object orientated. The object of work forms the basis for the "motive" of the activity: what the phenomenon to be studied is, how it is understood, and why it is studied (Leont'ev 1978). The object and result of a certain work process is related to other societal activities. Any work process must be analyzed in the network of other societal activities. Analytic chemistry produces methods and results that are used, for instance, in environmental research and quality control of metal industry. To understand the nature and content of the work in a specific analytic research laboratory, it is important to understand the sources of the object of research.

On the basis of this conception the following questions concerning the work of the analytic section of the Reactor Laboratory were formulated:

1) How were the objects of research formed, and how have they influenced on the analytic activity and the development of its methods?
2) How were the tools and instruments developed, and how has this development influenced laboratory work?
3) How did the division of labour between researchers and laboratory assistants develop?

The data of the study consists of interviews, publications, project plans and memos, and of observations and notes of unofficial coffee meetings of the section. The interviews were done at different times and in different situations in 1987, 1988 and 1990. The relation of the interviewees to the work process differed. Hence, they provide a multitude of narratives, with different interpretations, about the development of work. It has been tried to allow the voices of the researchers and research assistants to speak in the study. By this procedure I have tried to retain the richness, the *multi-voicedness* of activity – to use the concept of Mikhail Bakhtin. The aim has been to reach cultural sensitivity and historical specificity in the analysis of the activity (Calhoun 1990). Moreover, it seems important, in science studies to let the researchers of different fields, to speak about the nature and the problems of their work.

## The complementary levels of analysis

To understand the particularities of NAA-work in the Reactor Laboratory at least five cultural determinants should be taken into account. The first and second of them refer to the general cultural characteristics of the tools of the work. The remaining three refer to the national, economic and organizational determinants of the work.

1) NAA-work is analytic chemistry. It is one of the modern methods of analytic chemistry. It shares problems typical to this discipline. Analytical chemistry always works with real analytical samples – industrial, geological, biological or environmental – the composition of which are never known beforehand (Hulanicki 1986, 14). It is interdisciplinary, oriented to using chemical, physical or biological methods. The typical problems of analytical chemistry are interferences and matrix effects. When measuring a certain element from the sample, the other elements and the chemical composition of the sample (matrix) influence the behaviour of the element under scrutiny. No analytical method or apparatus is free from matrix effect. As a result, these effects have always to be taken into account when a new kind of sample is measured.

The formulation of this problem (matrix effect) and the principles and procedures to handle it (developed within analytic chemistry) are culturally generalized artefacts, generalizations of collective practice. They help to understand what is happening in a laboratory – of course in a specific form, because the real analytics is always done with a specific method and instrument and with specific samples.

2) NAA-work is an application of the neutron activation analysis method. In NAA the samples are irradiated in the neutron flux of a nuclear reactor. Elements of the sample become radioactive isotopes and the characteristic gamma-radiation of the isotopes can be measured. NAA is tied to the neutron source, a nuclear reactor. The rule is: where there are research reactors, there is NAA done. The method is tied to the fate of the few hundred research reactors (443 in the whole world in 1986) that were founded as part of the civil nuclear energy programs in the 1950's and 1960's. NAA as a method will survive as long as the research reactors survive. Already in the 1970's more research reactors were shut down than commissioned and this trend is accelerating.

NAA has its own scientific community. Every fourth year the International Conference on Modern Trends in Activation Analysis is held. The methodological problems are discussed, and the results are delivered in these conferences. NAA is one method of analysis competing with other methods. It has strong and weak points (Revel 1987). The specific characteristics of the method explain to what elements, what kinds of samples and what kinds of problems it is used. NAA can also be regarded from the point of view of its life cycle and from its comparative advantage to other developing methods (Girardi 1982). The NAA-work in the Reactor Laboratory can be interpreted as a part and a specific case of the broader development of the method.

3) The NAA-work studied here is done in a small, semiperipheral industrialized country (Finland). The characteristics of a small industrialized country like Finland influence the demand for analytic services. Research expenditures are scarce. The Finnish strategy of economic growth is based on the "exploitation of the advantageous position of the follower" (Lemola & Lovio 1988). The role of research has mainly had the character of transferring technology or following the progress of the technological frontier of international basic electronics technology. Advanced chemical analytics develop in close connection with the basic research in other fields. That is why the national particularities of research and industrial development influence the problems and objects of the analytical work, and the possibilities and the contents of the analytical research itself.

4) NAA-work is done in a research Institute with – among other things – a specific financing system. The Technical Research Centre of Finland is a n unusual kind of public research institute. All fields of technology are concentrated into one institute. The Centre has traditionally received the major part of its funds from the state budget. During the 1970's the situation changed radically. In the beginning of the 1970's the share of budget money in the research centre's operating

expenditures was about 60 %. By 1988 it had decreased to 34 %. Service research and the responsibility for the financial "results" (acquisition of money for projects) has become more and more important. This change had a profound impact on the nature of research work.

5) NAA work is done in a specific unit (the Reactor Laboratory) of the Centre. The Reactor Laboratory has its own characteristic features among the laboratories of Technical Research Centre. It was removed to the Research Centre from the Technical University of Helsinki in 1971. The academic tradition of producing many dissertation and other publications is strong, and not typical of many of the engineering laboratories in the Research Centre. The researchers of the analytic division have mainly been radio chemists, and half of them have been women (79 % of the researchers in VTT are males and 78 % engineers). These features influence the way the research is done and the relations between researchers and research assistants.

In sociological laboratory studies microanalysis and the local, contingent, idiosyncratic and opportunistic nature of laboratory practice have been stressed (Knorr-Cetina 1983). On the basis of the above-said it is quite logical, that in any concrete laboratory work both micro and macro, both the general and the particular, are present. But the macro- or general aspect of work cannot be found inside the walls of laboratory without analyzing the generalized cultural and instrumental aspects of the work. The real societal is found in the tension between the generalized cultural content and cultural intermediation of the work, and the particular circumstances and special characteristics of work in a laboratory. Accordingly, a continuous interaction between the levels of analysis is needed in the research process (Cicourel 1981).

## The NAA method in the Reactor Laboratory

Neutron activation analysis is very sensitive method for analyzing contents of elements in different materials. The results are expressed in general in terms of parts per million (ppm). This means that very small amounts of elements are detected. This high sensitivity is needed in many fields, such as environmental research or semiconductor production. For instance, the mercury content of biological material is normally 0.01–0.05 ppm (Häsänen 1970, 251).

In the NAA the sample is put into the nuclear reactor, the Triga Mk II research reactor in the Reactor Laboratory. The elements of the sample are changed into radioactive isotopes in the neutron flux of the reactor. The atomic nuclei of radioisotopes are unstable and emit gamma rays. The gamma rays of each isotope have definite energies and hence they can be detected by a gamma-ray spectrometer. This apparatus is composed of a detector (Nal(TI) cristal or GE-semiconductor), and the transistorized multichannel analyzer, which sorts the gamma-rays to different channels according to their energy level. As a result a gamma spectrum of the sample is received. Simultaneously with the samples, a standard sample is irradiated. The quantities of the elements in the standard are known. The concentrations of samples can be calculated by comparing their spectra to the spectrum of the standard.

The “instrument” of the NAA is actually quite a huge technical system. It is composed of the reactor with its implementations like the pneumatic transfer system to get the samples into the reactor, and the automatic gamma ray analyzerwith its sample changer and computer.

The problem in the development of methods can be described as follows. Different isotopes have very different half-lives (from minutes to years) and hence they are active for different periods. On the other hand different isotopes have gamma-rays of the same energy and this can interfere with the measurement. When measuring a certain type of sample where certain elements should be detected, the irradiation (type, intensity, time), the decay time before measurement and the measurement time should be designed in such a way, that the irradiation ‘peaks’ of the elements to be detected can be measured without interference of other elements in the sample. This is a complex task. On the basis of the knowledge concerning the nuclear characteristics of the isotopes and the possible composition of the sample, a hypothesis of a good procedure can be made. But the composition of the samples is not known well beforehand and that is why experimentation is always necessary. The problem is still more complicated when many elements are to be measured from the same sample (multielemental analysis).

As a result of experimentation, an optimal procedure of detection is developed and documented. For instance, in a routine method of analyzing 11 lanthanides from geological samples, the samples are irradiated for one week, one lanthanide is measured eight days after the irradiation, five of them nine days after irradiation (with a different detector), and the rest of them four weeks after the irradiation. The whole process takes five weeks and is always done in the same way.

But what kinds of samples are the methods being developed for, and where do the objects of analysis come from? The concepts ‘analysis’ and ‘type of sample’ are in many ways connected to societal practices (Nygård & Petterson 1990, 186). The objects literally determine the nature and content of the method to be developed and in addition, to a large extent create the motive of the analytic work and method developing.

## The development of the NAA work in the analytic section

In the international level, the three principal application fields of NAA are biology, geology and environmental studies. The distribution of papers given in the 7th International conference on Modern Trends in Activation analysis in 1986 was as follows: biology 31 %, geology 27 %, environmental studies 26 %, metals and semi-conductors 10 % and the rest 5 % (Revel 1987, 178). In the Reactor laboratory the main fields have been environmental research and geological research. In the beginning there was a strong deal of national service research. All those who needed analysis of very small amounts of elements, not accessible to other analytical methods, were to get them from the Reactor Laboratory. As a result very many types of samples were studied. In the words of the researchers (Rosenberg & Lakomaa 1983, 18):

> The richness of the service analytics has been in the diversity of samples. It is difficult to imagine a type of sample that hasn't been analyzed. Geology, ore prospecting, metallurgy, paper industry, toy industry, crime investigation, archaeology, ect. have been represented.

The 25 years of NAA-work in the Reactor Laboratory can be divided into five stages (Table 1.1). In every stage the emphasis of the research has been on a certain type of samples. Research in NAA-work is the development of methods for certain kinds of samples. The "type of samples" can be defined by studying who needs the results, of what elements, and why.

The division presented in Table 1 is schematic. Environmental research, for instance, has continued also in the years 1976–1986. But the phases help to describe the cyclic nature of the activity and the dynamics of reorientation in NAA work. In addition each phase has its own story to tell.